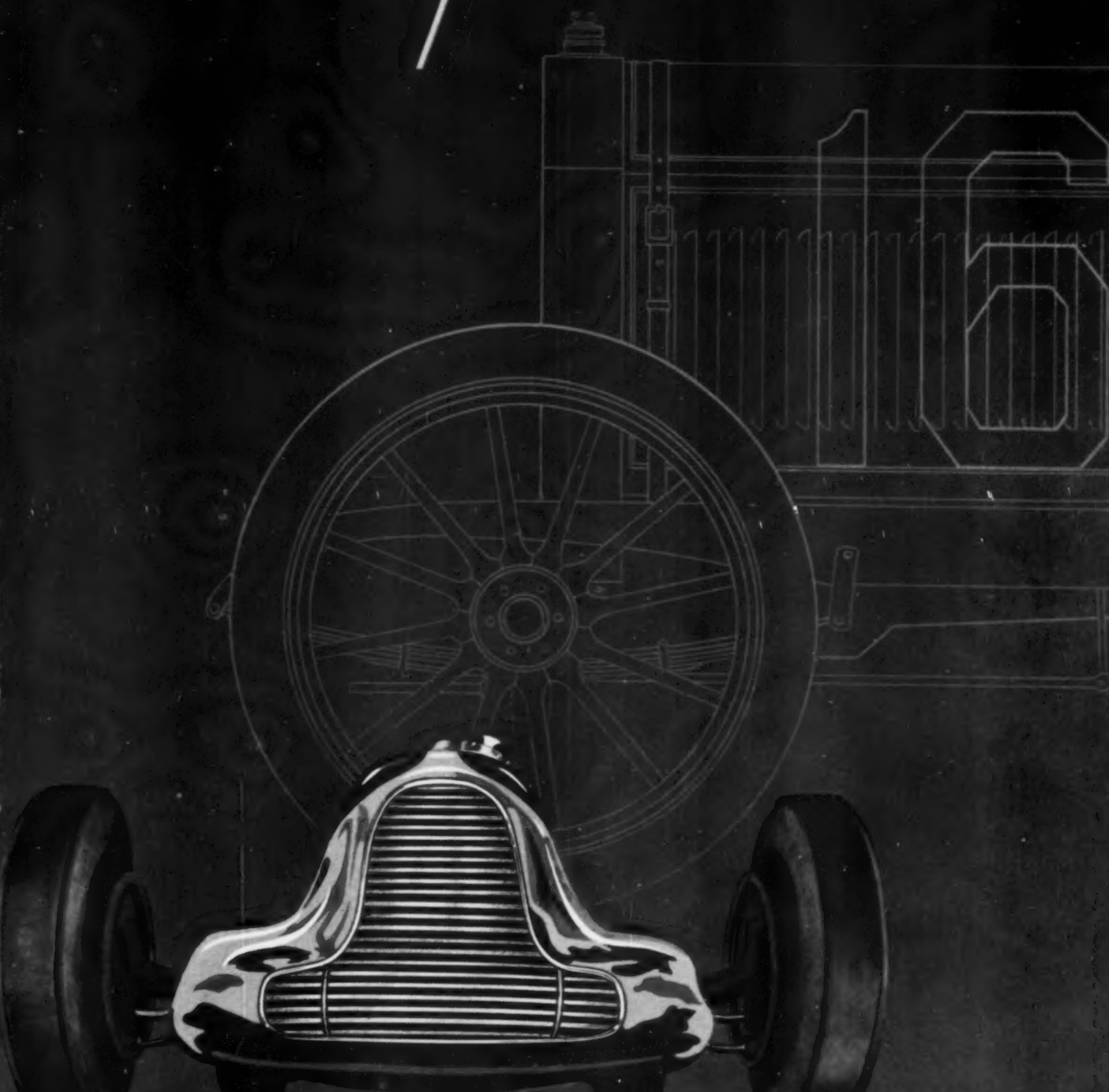
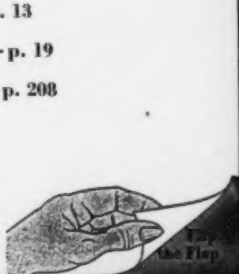
METAL Progress



IN THIS ISSUE

The cover design contrasting the old and new in racing cars won an honorable mention for Aldrich J. Hansal in *Metal Progress*'s annual competition for students at Cleveland School of Art



IT HAS BEEN my privilege to attend meetings of the Trustees of the Society for 34 years, and since the Board meets four times a year, I have attended 136 meetings, minus one-half. That half was in January 1921 when a heating system that refused to work contributed considerably to a case of quinsy (not Kinsey); I attended the session in the morning, but the Trustees sent me home after lunch.

The most important meeting the Board has held in many a year took place in National Headquarters in Cleveland on July 31, 1952. On that day the Board established the American Society for Metals Foundation for Education and Research with a starting endowment of $650,000.00.

To bring you up to date, the idea for the Foundation was suggested to the Board in a communication from the Secretary presented at the meeting on Jan. 31, 1952. The event in the life of the Society which prompted me to make this suggestion was the enactment of new provisions of the Internal Revenue Code pertaining to tax-exempt organizations, under which the Society operates. The Society has been fortunate that in all 34 years of its existence, with one exception (1932), there has been an excess of income over expenditure. This accumulated reserve is now of sufficient size that the income from this fund, together with the current excess of income over expense, should be made available for financing worthy projects.

The Foundation was incorporated under the laws of Ohio, and, upon ratification by the membership at the annual meeting in Philadelphia on Oct. 23, will receive a total of $650,000 in cash or in equivalent securities. The principal of this fund may not be expended. Only the income from the invested principal will be available for appropriation by the trustees of the Foundation. These trustees are the president and the four immediate past-presidents of the Society, each serving five years. The governing board of the Foundation will consist of the following past-presidents: Harold Work, Arthur Focke, Walter Jominy, John Chipman, and the incoming president, Ralph Wilson. The income for the first year will be between $25,000 and $30,000. It is contemplated that the Society may make additional contributions to the Foundation as the trustees may deem advisable and desirable.

As I stated before, the incorporation papers have been filed. The original meeting of the trustees of the Foundation has been held. The funds, consisting of stocks and bonds which are to be allocated to the Foundation, have already been set aside. Nevertheless, not one of these activities will become operative or legal until the entire activity has been approved at the next annual meeting of the Society in October.

When one takes into consideration the fact that the Society was devoid of funds some 34 years ago—in fact, was $1400 in debt—it must be a matter of pride, not only to the present members but to those who have given their time and help during the early periods, that the Society has become recognized as the Engineering Society of the Metals Industry, and that its accumulated funds are being devoted to education and research in the metals field. Complete details of the Foundation will appear in the September issue of *Metals Review*.

I feel this Foundation is a step in the right direction, and I am mighty pleased indeed not only to have had the honor of proposing this Foundation, but also the privilege of being a participant in the management and a member of the ASM Board during all the 34 years the funds were being accumulated that made this Foundation possible.

Cordially yours,

Bill

W. H. Eisenman, *Secretary*
American Society for Metals

THERMALLOY

Muffles and Baskets...

Thermalloy baskets stacked four high with lift strap

Shaker hearth muffle

provide lowest cost per operating hour

In countless heat-treat applications, users find that THERMALLOY* muffles and baskets give longer hours of service . . . more operating hours per dollar. Here's why:

- X-ray inspection of both welds and castings assures shipment of muffles that will give long, trouble-free service.
- Close analysis control of Thermalloy develops optimum strength and ductility to resist cracking, warping and sagging.

Whether you need muffles or baskets—retorts, trays, fixtures, chain conveyors or other heat-treat equipment—investigate Thermalloy! It will help you get longer service life per dollar.

For recommendations on your specific needs, call your nearest Electro-Alloys representative. Or write Electro-Alloys Division, 2101 Taylor Street, Elyria, Ohio.

*Reg. U. S. Pat. Off.

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION

ELYRIA, OHIO

The trend is to more forgings with BLISS Presses

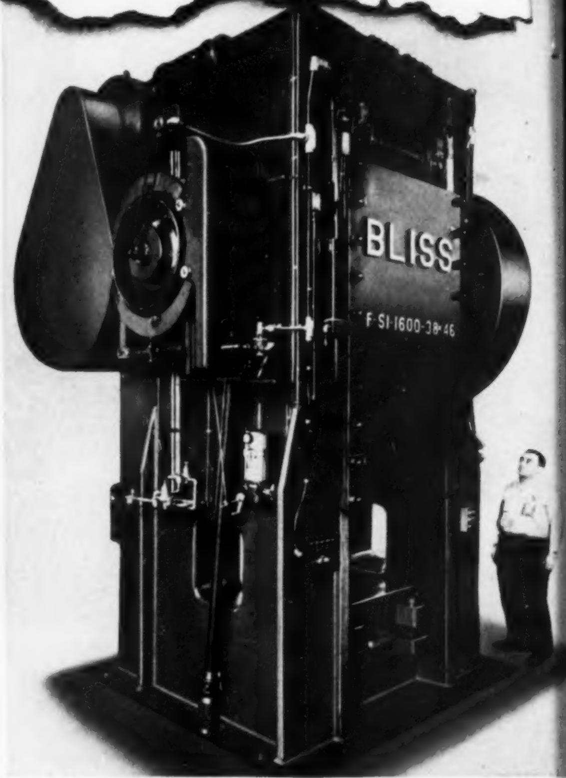
Here are the "Plus" Features of the New Bliss Forging Press:

Easily adjusted die seat: The wedge-type die seat permits easy, positive adjustment.

Withstands severe usage: A specially-designed Bliss heavy-duty air friction clutch and an air release spring brake, both mounted on a full eccentric main shaft, permit fast press speeds on 'round-the-clock production runs.

Die alignment maintained even when off-center loads are applied, because front of slide has long, continuous gib ways extending up into crown.

For complete information on the new Bliss line of High-Speed Forging Presses, write for Catalog 42.



New Bliss Forging Press for high production to be built in a wide range of sizes with capacities up to 4,000 tons.

BLISS

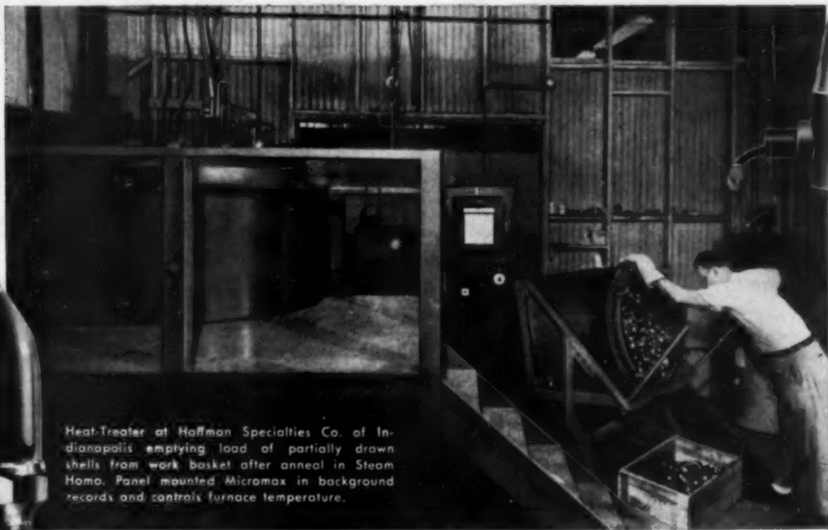
ON YOUR PRESS IS MORE THAN A NAME...IT'S A GUARANTEE!

E. W. BLISS COMPANY, CANTON, OHIO
E. W. Bliss (England) Ltd., Derby, England
E. W. Bliss Company (Paris), St. Ouen sur Seine, France

PRESSES, ROLLING MILLS, SPECIAL MACHINERY

Branch Offices in Chicago, Cleveland, Dayton, Detroit, Indianapolis, New Haven, New York, Philadelphia, Rochester, Toledo, and Toronto, Canada. **West Coast Representatives:** Moore Machinery Co., Los Angeles and San Francisco; Star Machinery Company, Seattle. Other dealers in United States and cities throughout the world.

Jrl. Ad. T-620(36)



Heat-Treater at Hoffman Specialties Co. of Indianapolis emptying load of partially drawn shells from work basket after anneal in Steam Homo. Panel mounted Micromax in background records and controls furnace temperature.

Hoffman Specialties Co. reports on Steam Homo

"Increased Uniformity...Increased Quality of Brass Parts"

• Scale-free heat-treating of both non-ferrous and ferrous parts at temperatures to 1150 F is one of the big jobs that the versatile L&N Steam Homo is doing for industry. Brass and bronze parts, for example, are treated so effectively that they come out of the furnace not only uniform in quality, but really clean . . . many times ready for use "as is."

The experience of the Hoffman Specialties Co., manufacturers of heating system products, illustrates these points. They have noticed that Steam Homo does even more than increase the uniformity and quality of product components. There is also an increase in the life of the tools used on their products in operations following heat-treatment. This is attributed by Hoffman to two factors: (1) Uniformity in hardness of treated parts. (2) Better adherence of lubricants to treated parts.

Hoffman's experience is typical of many users. Wherever a steam atmosphere is indicated . . . for steam-treating high speed cutting tools . . . for safely and uniformly bluing iron and steel parts or for steam-treating powdered iron compacts after sintering L&N Steam Homo is being enthusiastically received and successfully applied.

Safe, compact Steam Homo equipment is ideal for installation directly in production lines. It can be placed on the floor (as above) or sunk in a pit. Check the advantages of this furnace with your nearest L&N representative or write 4927 Stenton Ave., Phila. 44, Pa.

For full information about Steam Homo, send for the NEW 12 page catalog, "L&N Steam Homo Method for Heat-Treating."

CAREER OPPORTUNITIES AT L&N

Expansion program of this long-established firm has many features to attract outstanding recent graduates in engineering and science. Opportunities are in sales field engineering, product and application engineering, research, advertising, market development. Widely-respected policies assure recognition of progress. Address Personnel Manager for preliminary interview at nearest of 17 L&N offices.

LEEDS NORTHRUP

Instruments automatic controls furnaces

Metal Progress is published and copyrighted, 1952, by American Society for Metals, 7301 Euclid Avenue, Cleveland, Ohio. Issued monthly; subscriptions $7.50 a year. Entered as second-class matter Feb. 7, 1921, at the post office at Cleveland, Ohio, under the act of March 3, 1879.

Cam — Sand-cast.

Valve bodies — Sand-cast.

Bushing material—Centrifugally-cast Ampco Grade 18 bars, standard 12½" lengths.

—use AMPCO* METAL

Today's production schedules are demanding. They call for machines that are tough — machines that can take it hour after hour, day after day, month after month.

Designers and plant operating men are using Ampco Metal to build this extra toughness, longer life into their products and equipment.

Here's why: Ampco Metal has high compressive strength — doesn't squash out. It resists abrasion, corrosion and erosion. These properties plus high impact, high fatigue values and excellent bearing qualities make Ampco Metal ideally suited for the toughest kind of service.

You can get Ampco Metal in a variety of forms —sand and centrifugal castings, bars, forgings, sheet, plate, tubes, arc welding electrodes and wire, etc.

Enjoy higher production, freedom from trouble in both product and plant — use Ampco Metal. Your nearest Ampco field engineer is glad to help you on any application. Consult him or write us for additional information.

*Reg. U. S. Pat. Off., Ampco Metal, Inc.

Clutch ring — Centrifugally-cast.

Tear out this coupon and mail today!

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9-10

"Investigated all types, Bought Westinghouse"

...says Leading Tool Steel Producer

"Our Westinghouse gas-fired rectangular bell furnace has greatly increased our production of high-quality steel. It enables us to meet stringent customer decarburization specifications. Rejects have been virtually eliminated. Several costly production operations have been reduced or are entirely avoided"... reports this leading producer of tool and specialty steels.

"We investigated all types before purchasing this furnace. In our opinion, Westinghouse was the best engineered, and offered the most atmospheric control on the market. To meet the demands for more production, we have just purchased another Westinghouse furnace."

Gas-fired or electric, there's a Westinghouse furnace to meet your heat-treating need. For toolroom application or continuous-line, high production, it's your assurance of an unbiased answer to your all-important problem. Get the facts from your Westinghouse representative. Write today for new 40-page book, B-5459, "Harnessing Heat." Westinghouse Electric Corporation, Industrial Heating Department, Meadville, Pa. J-10377

Westinghouse

HEAT-TREATING FURNACES

$6,000 SAVED BY SWITCH TO SUN QUENCHING OIL

For years, a large New England manufacturer used a high-priced oil for all quenching operations. Two years ago, a Sun representative recommended Sun Quenching Oil, a much less costly product.

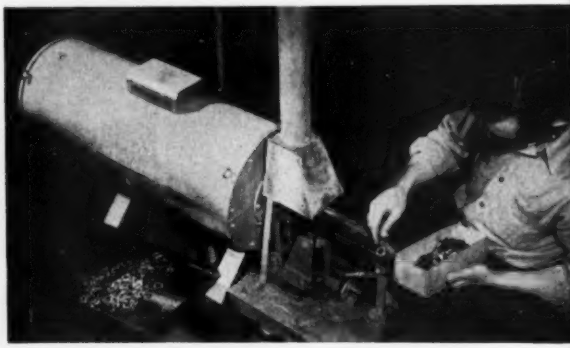
After a thorough test, Sun Quenching Oil proved itself equal to the expensive oil—better, in fact, because less oil was carried off on the parts. By using this product for all quenching operations, the manufacturer is now saving about $3,000 a year.

Sun Quenching Oils give consistently uniform results. They drain off rapidly, keeping dragout to a minimum. They have long service life, and under normal conditions never have to be replaced. *Sun Quenching Oils meet the requirements of 95 percent of all quenching operations.*

An informative booklet "Sun Quenching Oils," or the service of a Sun representative is yours for the asking.

BIG ANNUAL SAVINGS. The much lower cost of Sun Quenching Oil, plus the elimination of excessive dragout, has saved this company more than $3,000 a year. Here parts from a salt pot are quenched in the Sun product.

15 PERCENT LESS OIL CONSUMED, because of reduced dragout, since switching from an expensive compounded product to Sun Quenching Oil. Here parts are quenched in the oil after coming from a hardening furnace.



UNIFORM PERFORMANCE. Sun Quenching Oil has produced uniform results in this plant for more than two years. These small parts get a bright quench after they leave the miniature shaker hearth.

SUN INDUSTRIAL PRODUCTS

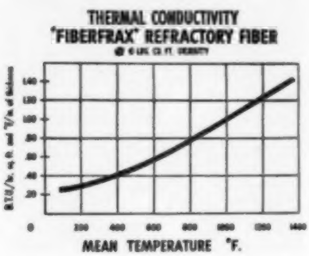
SUN OIL COMPANY, PHILADELPHIA 3, PA. • SUN OIL COMPANY, LTD., TORONTO AND MONTREAL

SUNOCO

Engineering Digest

OF NEW PRODUCTS

FURNACE INSULATION: A new man-made fiber trademarked Fiberfrax, announced by the Carborundum Co., has high heat resistance, light weight, and low heat transmission which make it competitive for industrial furnace insulation. Its attendant properties make it desirable for use in the aviation, electrical, papermaking, and chemical fields also. Fiberfrax fiber

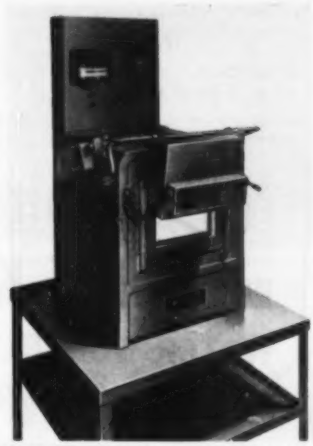


is made by melting aluminum oxide and sand in an electric furnace, then subjecting a stream of the molten lavalike material to a controlled blast of air. The molten material is blown into a fluffy mass made up of random arrangements of extremely fine fibers. The fibers range up to 3 in. in length and have an average thickness of about 1/25 that of a human hair. The fiber easily withstands 2300° F. without loss of properties and does not soften at temperatures approaching 3000° F. Basically the product is a vitreous ceramic, rather than crystalline. Insulation tests show that Fiberfrax fiber, as compared to high-quality refractory insulating brick, can make impressive savings in weight and furnace efficiency. The savings are significant enough to make the material directly competitive even at the pilot-plant price of $1.00 a pound. Compared to high-quality cemented refractory insulating brick, tests show that 30% less electrical power is required to maintain furnace equilibrium at 2500° F.; time required to bring the furnace up to temperature is cut in half.
For further information circle No. 620 on literature request card on p. 32B

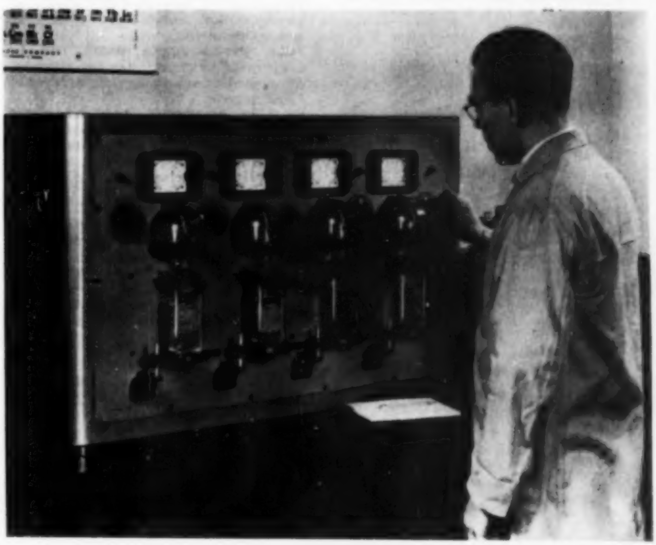
ROLLING THIN STRIP: Custom rolling of most ferrous and nonferrous ultra-thin, high-precision metal strip is now available to industry from American Silver Co. Facilities include 4-high and Sendzimir cluster rolling mills, close-tolerance slitting and shearing lines, and continuous atmosphere annealing furnaces. Strip can be supplied in widths up to 8 in. and thicknesses down to 0.0005 in. Generally, gage tolerances of plus-or-minus 0.0002 in. are held on thicknesses from 0.010 to 0.006 in.; tolerances of plus-or-minus 0.0001 in. are held on thicknesses below 0.006 in.
For further information circle No. 621 on literature request card on p. 32B.

HEAT RESISTANT PAINT: A new gold-colored heat resistant paint has been announced by Speco, Inc. Made of copper flakes in a silicone base, the new paint will withstand temperatures up to 1700° F., according to the manufacturer, and will air-dry in 30 min. Because of its high copper content, the coating prevents rust and is resistant to corrosion from mild acids, alkalies and industrial fumes. It is recommended for ovens, exhaust manifolds, heat lines, compressors, engine heads, and high-pressure boilers.
For further information circle No. 623 on literature request card on p. 32B.

HEAT TREATING FURNACE: The Cooley Electric Mfg. Corp. has announced a new addition to its line of heat treating furnaces and ovens. The new VK-7 bench model has



ELECTRO-ANALYZER: The new Fisher electro-analyzer makes it possible to run separate or duplicate analyses at the same time. The electro-analyzer offers 10 volts at 10 amp., and a-c. ripple, a serious shortcoming in earlier instruments, is held to less than 2%. As the rate of deposition is greatly altered by the temperature of the sample, close temperature control is provided by a 200-watt thermostated heater. A stirring motor is located at each sample station. A wide variety of accessories are available for specific laboratory needs.
For further information circle No. 622 on literature request card on p. 32B.



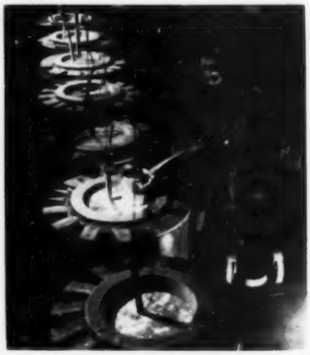
chamber dimensions of 10 by 6 by 18 in. Heating elements of 6.5-kw. capacity at 220-v. single phase, on all four sides of the chamber and in the door, provide even heat distribution. The elements are of embedded design, which protects the element wire against atmospheric attacks and mechanical breakage. Elements can be renewed without dismantling the furnace.

For further information circle No. 624 on literature request card on p. 32B.

TOOL STEEL: The Steel and Tube Div. of Timken Roller Bearing Co. has announced Graph-Mo Hollow-Bar, a turned and bored bar section using for the basic material Graph-Mo tool steel. It will have all the advantages of graphitic tool steel plus the convenience of the hollow bar section in manufacturing ring gages, dies and other annular tool steel parts. Stock sizes range from 4 to 16 in. o.d. with a variety of wall thicknesses.

For further information circle No. 625 on literature request card on p. 32B.

INSULATING POWDER: The uncertainty of the current aluminum supply makes it more important than ever that this metal be protected from contamination by iron in melting, alloying, and casting operations. A number of substances are used to form slurry coatings which will minimize such ferrous pick-up and at the same time protect valuable foundry equipment. Among these is Insulating Powder R-20, a product of Aluminum Ore Co. The R-20 coatings are applied to molds, ladles, melting



pots, pouring troughs, tools used for mixing, alloying and cleaning, and to any other ferrous metal equipment which comes into contact with molten aluminum.

For further information circle No. 626 on literature request card on p. 32B.

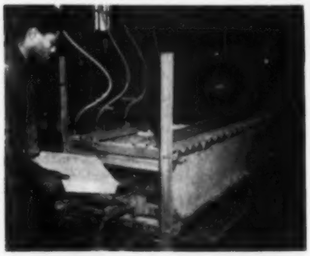
DEGREASER: The Curran Ordnance Chemical Laboratory has developed a high-performance degreasing solvent, especially formulated for use in recirculation solvent degreasing machines employing a flow of solvents over the parts while they are being brushed. High cutting action and quick, clean evaporation assure good performance. According to the company, the product is noncorrosive and harmless to all makes and types of solvent recirculation machines.

For further information circle No. 627 on literature request card on p. 32B.

BRAZING ALLOY: Handy & Harman has announced the development of a new metal joining composition known as "EB" silver brazing alloy. It is intended primarily for use in brazing chromium carbide, cast carbides and other "hard-to-wet" carbides. Effective results have also been obtained on tungsten-copper alloy, cermets and other refractory alloys difficult to braze. The new alloy is 57% silver plus copper, manganese and tin. It has a solidus of 1120° F. and a flow point of 1345° F. There are no volatile elements in this

alloy, an important factor in vacuum applications, and it is not susceptible to the dezincification type of corrosion.
For further information circle No. 628 on literature request card on p. 32B.

INFRARED HEATERS: Precision plaster molds, used for aluminum casting, can be dried evenly and precisely with far-infrared electric heat. In one application the first 8 ft. of a 12 ft. oven are heated by 36 Wiegand



Chromalox radiant heaters with a total capacity of 39.6 kw. The longer far-infrared wave length is absorbed efficiently even by white materials, with negligible reflection, and rapid heating results in short conveyer travel.
For further information circle No. 629 on literature request card on p. 32B.

TUMBLERS FOR SMALL PARTS: Tumb-L-Matic, Inc., announces a new tumbling barrel having individual "pockets" for tumbling from two to six items at a time. The tumbler, recommended for deburring, precision finishing and polishing small parts, comprises a rotating container into which the pockets fit. By having an extra supply of pockets, loading and

unloading can be accomplished while other pockets are being tumbled and a nearly continuous batch operation can be achieved. Tumblers are available with frames for handling from 2 to 6 pockets. Pockets range from 12 to 16 in. in diameter. The outer box-container holds water during tumbling. Also available is the self-contained type which can be adapted

for either wet or dry operation. This type does not have the outer box-container but water can be added to the individual pockets when desired.
For further information circle No. 630 on literature request card on p. 32B.

TEMPERATURE CONTROLLER: For accurately controlling temperatures from minus 100° F. to plus 600° F., Thermo Electric Co., Inc., is introducing their newly designed Thermo Electronic temperature controllers using resistance-bulb-sensitive elements. The instrument has a relay with load contacts for operating heating elements, motor starters, electric valves, and signal contacts for the two red and green lights on the instrument door. When the temperature at the resistance bulb deviates as

little as 0.1° F. from the control point setting, the instrument takes immediate corrective action. The control action is continuous.
For further information circle No. 631 on literature request card on p. 32B.

INERT ARC WELDING: Spekaluminite Co. has announced Weldaluminite, for extending the application of inert arc welding to rimmed steel. Weldaluminite contains aluminum which deoxidizes the weld pool and is so formulated that it retains the aluminum at the point of welding. The agent is either sprayed or brushed on the joint to be welded and allowed to dry before welding is begun.
For further information circle No. 632 on literature request card on p. 32B.

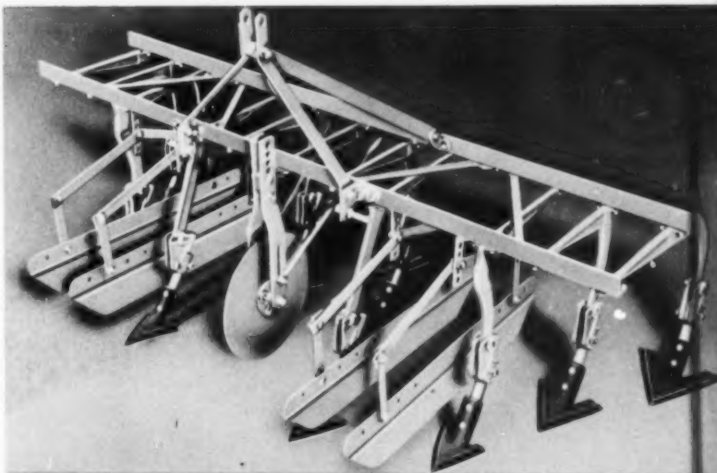
BELT GRINDING: A new concept of portable grinding is the result of an attachment which permits the use of abrasive belts on straight-spindle air and electric portable tools. Announced jointly by the Carborundum Co. and Buckeye Tool Corp., the new

Facts you should know about U·S·S CARILLOY STEELS

In lift-type cultivators U·S·S Carilloy steels save weight, increase durability, and keep down costs

● To pack maximum strength into their heavy-duty lift-type cultivators, while keeping weight as low as possible, Pittsburgh Forgings Company uses U·S·S CARILLOY steels in the shanks, beams, and main frames of these rugged farm implements.

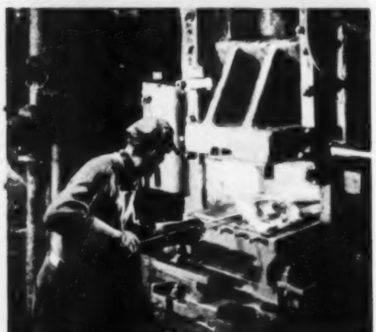
The excellent performance of this equipment is proof that many parts that must operate in extremely tough service can be made of alloy steels that do not contain critical elements. The three grades of U·S·S CARILLOY used in this application—CARILLOY 5130, 5135, and 5140—were selected years ago for the express purpose of providing minimum weight, maximum strength and durability, at the lowest possible cost.



Pittsburgh Forgings Company uses U·S·S CARILLOY 5130, 5135, and 5140 in the heavily stressed parts of this lightweight cultivator (400 lbs.) to provide minimum weight, and maximum strength and durability, at lowest possible cost.

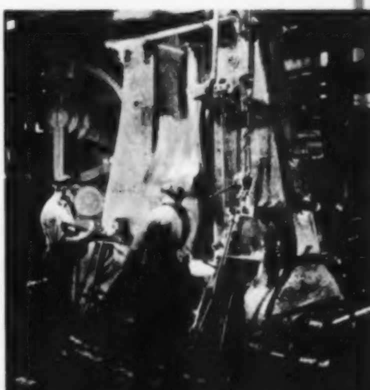
CARILLOY steel construction provides the strength and toughness required to cultivate heavy soil at speeds up to 6 miles per hour, and has made it possible to reduce cultivator weight to only 400 lbs. This is about half that of comparable units made of ordinary carbon steel, and well below the limit which the tractor lifting mechanism is designed to carry.

Excess metal left after forging is removed in this trim press. The piece is then straightened, bolt holes are drilled, and surfaces that must align exactly with other parts are accurately milled.



In this equipment, U·S·S CARILLOY alloy steel not only provides increased strength, greater durability, and added resistance to wear. By making it possible to safely decrease the size and weight of all heavily stressed parts, it reduces the amount of steel required, and enables the manufacturer to keep his costs well in line with competition.

U·S·S Metallurgists who have had wide experience with similar applications of alloy steels, will be glad to assist you in selecting the steel best suited to your product. They can also recommend the best heat treating methods to use. If you need their help just call the nearest District Sales Office, or write to United States Steel, 525 William Penn Place, Pittsburgh 30, Pa.



At Pittsburgh Forgings Company, precision parts for lift-type cultivators are forged from U·S·S CARILLOY bar stock. Here, beams are being forged to final size and shape in a steam hammer.

USS

UNITED STATES STEEL COMPANY, PITTSBURGH · COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO
TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA. · UNITED STATES STEEL SUPPLY DIVISION, WAREHOUSE DISTRIBUTORS
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

UNITED STATES STEEL

"We get a better job because

says William Saunders — U. S. STEEL

● Bill Saunders is a Manipulator Operator at our Homestead District Works Forge Department. He has the keen eye that comes from 9 years as a Crane Operator plus 16 years as a Manipulator Operator—the last 5 years with the same crew of men.

In case you've never watched a manipulator, it straddles the pit in front of a forging press; its powerful jaws clutch a 40 or 50 ton ingot when rotating and positioning it between the press dies. But the only way to understand why the manipulator man is so important is to actually talk to him. If you had a chance to talk to Bill Saunders, here's the way the conversation might go:

YOU: *"What's that piece you're forging now?"*

SAUNDERS: "It's a vertical column for a drop hammer. When we finish forging, it'll be cut in half to make two columns. This is an easy forging job."

YOU: *"An easy one? Then what makes a tough one?"*

SAUNDERS: "Rectangular blocks, for instance. They're hard to manipulate because we don't have any excess metal for the jaws to grab. I have to operate the jaws so they'll hold the piece tight, but not so tight that the piece is deformed. The blocks are usually short, and the manipulator has to work close to the press, so I have to be sure the jaws don't get caught in the press."

YOU: *"Who actually runs the whole operation?"*

SAUNDERS: "The Pressman—that's the fellow down by the press. We've been working together for over 5 years, and I can almost tell in advance just how he wants the piece positioned. That's one reason why we work so fast."

YOU: *"Doesn't working fast lower the quality of the job?"*

SAUNDERS: "No—it gives *better* quality. You see, if you fumble around with a piece too long, it'll cool off. That's not a big problem with ordinary carbon steel, but we'd ruin a high alloy or stainless ingot if we worked it too long. You can only work some of those stainless ingots about 5 minutes, then they have to go back to the furnace. We've *got* to work fast."

YOU: *"How about those big sleeves you make—how are they forged?"*

SAUNDERS: "First we take a 48 to 55 inch ingot and upset it into sort of a pumpkin or disc shape. Then we have big punches—they're just pieces of shafting—and we drive the punches down through the disc and make a hole in it."

YOU: *"You do all this on the forging press?"*

SAUNDERS: "Sure, we have to. After the hole is punched we insert a mandrel—a long shaft. Then this mandrel, with the forging hanging on it, is placed in the press opening and supported on V-blocks. Just think of an oversize pipe coupling slid over a piece of small rod. The upper press die comes down and works the top of the forging. The piece gets longer and the hole gets bigger while we work it."

YOU: *"Where does the manipulator come in?"*

SAUNDERS: "It does all the positioning for these operations. And then when we start forging, I rotate the mandrel and turn the piece so we can work it evenly."

YOU: *"I can see it's no easy job."*

SAUNDERS: "I'm just a small part of it. The Pressman, the men that operate the cranes and drive the press and the helpers—they're all important. Every man on the crew is an expert at his job, that's why we can work so fast. The customer gets a better product and he gets good delivery, too."

• • •

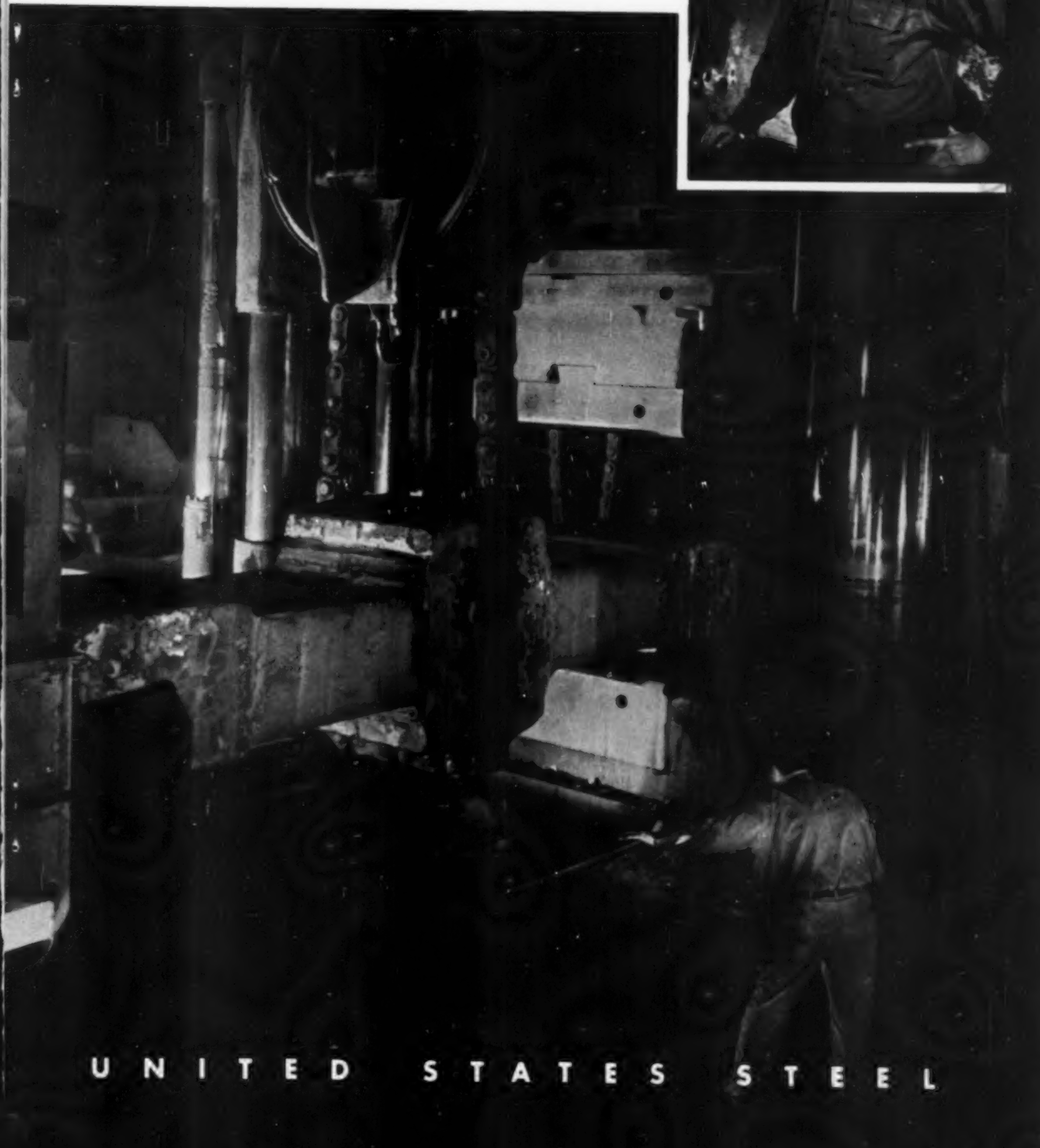
There's no such thing as a forging "production line." The quality of a forging is dependent almost solely on the individual skills of the men who actually make the forging. When you buy U·S·S Quality Forgings, able men like Bill Saunders work on them. With these men on the job, you can be sure of quality forgings—second to none. Please send inquiries to United States Steel Company, 525 William Penn Place, Pittsburgh 30, Pa.

USS *Quality* FORGINGS

- heavy machinery parts—carbon, alloy, stainless
- electrical and water wheel shafts
- hammer bases and columns
- marine forgings

we forge fast"

MANIPULATOR OPERATOR



Facts you should know about U·S·S CARILLOY STEELS

Non-critical Carilloy steel saves $40 a ton in gears of heavy-duty rotary pumps

Commercial Shearing & Stamping Company, of Youngstown, Ohio, is now using a non-critical grade of U·S·S CARILLOY steel in the precision gears of their heavy-duty gear-type hydraulic pumps. Commercial Shearing finds that the gears made from the new grade more than meet the rugged performance requirements of hydraulic service; and, in addition, the new grade costs $40 a ton less than the more critical alloy steel previously used.

Pumps operate at 1,500 psi and 2,000 rpm

These gear pumps operate at pressures as high as 1,500 psi and speeds up to 2,000 rpm; gear wear of only 0.005 inch causes a substantial drop in efficiency, indicating that a tough, wear-resistant steel is needed to assure good, reliable performance. The steel normally used was rich in critical elements. Because of availability, it became necessary to consider a grade containing less critical elements.

U·S·S Service Metallurgists were called in to recommend a suitable alternate steel. For this specific case, their advice was to use U·S·S CARILLOY 5120, an available straight-chrome alloy steel for the gears. It worked fine.

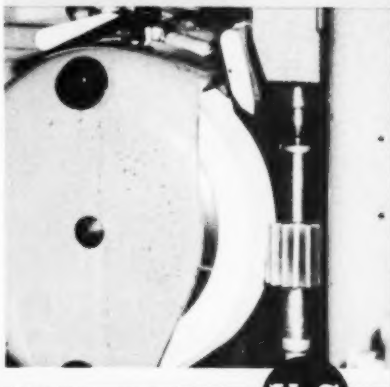
Easier machining and heat treating

Commenting on the performance of this steel, Mr. T. C. Kane, Chief Engineer at Commercial Shearing & Stamping Company, says, "We are frankly surprised at the excellent results we are getting with this new grade. Not only do the gears meet all our high performance standards, but we find this steel easier to machine and heat treat, and we pay a lower grade extra on it. All told, the new grade saves us $40 on every ton of steel we buy."

Used in the gears of these rotary pumps made by Commercial Shearing & Stamping Company, CARILLOY steel provides exceptionally tough, wear resistant gears that more than meet the rugged requirements of high-speed service.

This is the hobbing operation, the first step in machining these gears from bar stock.

The gears are finish machined to very close tolerances on precision grinders like this one. By changing from compositions containing critical alloying elements to those which are readily available, heat treating can be simplified, and, most important, costs can be reduced.



U·S·S metallurgical assistance available on any steel problem

Like Commercial Shearing & Stamping Company, thousands of manufacturers have benefited from the expert technical assistance of U·S·S Metallurgists. With wide experience in every phase of steel making and fabricating, they can help you to select the best steels for your products or to adapt your metallurgical techniques to obtain maximum performance from the steels you are now using. To obtain their help just call the nearest U·S·S District Sales Office or write to United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

UNITED STATES STEEL COMPANY, PITTSBURGH · COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO
TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA. · UNITED STATES STEEL SUPPLY DIVISION, WAREHOUSE DISTRIBUTORS
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

UNITED STATES STEEL

belt grinding attachment is made from lightweight aluminum castings, consists of an idler pulley, the supporting mechanism, and a contact wheel; the latter is mounted on the

tool spindle. Used in die and mold grinding, the attachment proves itself a real time saver. In weld grinding, only excess weld metal is removed, and metal areas around the weld are not ground.

For further information circle No. 633 on literature request card on p. 32B.

SUBZERO THERMOMETER: Model NR, a subzero recording thermometer made by the Dickson Co., provides a continuous time-temperature record on a 12-in. chart. The instrument is connected to the cold chamber by a stainless steel armored tube. Pen is motivated by a spiral Bourdon tube.

The "bulb", a brass tube ¾ in. in diameter and 11 in. long, is the only part of the instrument that needs to be in the cold chamber. The instrument is available in several scale ranges with extremes from −200° to +200° F.

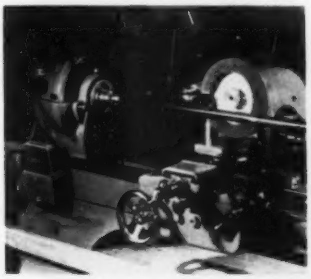
For further information circle No. 634 on literature request card on p. 32B

SURFACE COMPARATOR: A portable electronic surface comparator to determine surface roughness at the

point of production has been announced by Kota-Meters, Inc. The instrument, having a roughness range of 1 to 100 micro-in., evaluates the quality of a surface finish, and the index is indicated on a meter with the needle at an arrested or "frozen"

position. No visual or mental averaging is required. The probe of the instrument is hand-held and its shape and design permit universal use on radial, longitudinal, internal and external surface shapes.
For further information circle No. 635 on literature request card on p. 32B.

ABRASION TESTER: Taber Instrument Corp. has announced a new abrasion testing machine for rating the wear resistance of protective finishes such as black oxidized or electroplated coatings, extruded plastic and enamel applied to aircraft, ord-



nance and metal furniture tubing and other cylindrical parts or test pieces. The illustration shows a 34-in. rifle barrel being tested to determine the amount of wear the metal part will withstand before the blue oxide finish is worn thin, resulting in corrosion of the part. The test is performed by placing the gun barrel between two driving centers with the test surface in contact with the abrading head. The resulting wear is comparable to a gun being handled under field service conditions.
For further information circle No. 636 on literature request card on p. 32B.

What's new IN MANUFACTURERS' LITERATURE

637. Abrasive Unit
Bulletin 5205 on small dry-abrasive airblast unit for cutting hard materials and precision finishing. *S. S. White*

638. Alloy Steel
40-page book on heat treated alloy steel plate for maximum abrasion and impact resistance. Details on uses; 12 pp. of technical data. *Jones & Laughlin*

639. Alloy Steel
Data book on the selection of the proper alloy steel grades for each manufacturer's needs. *Wheelock, Lovejoy*

640. Alloy Steels
17-page booklet, "Alloy Steels and How to Get the Most Out of Them", contains seven case histories selected from widely varied fields. *Republic Steel*

641. Aluminum Alloys
36-page book on analysis of aluminum, brass, bronze alloy specifications. *Sonken-Galamba Corp.*

642. Aluminum Bronze
Bulletin PI-3 gives complete information on aluminum bronze as applied in corrosion-resistant service. Fully illustrated. *Ampco Metal, Inc.*

643. Aluminum Castings
Brochure "How To Cut Die-Casting Finishing Costs" deals with aluminum castings. *Monarch Aluminum*

644. Aluminum Fasteners
8-page illustrated booklet on all types of aluminum fasteners. Also accessories and screw machine products. *Alcoa*

645. Ammonia Dissociators
Bulletin on dissociating process gives advantages of ammonia as controlled atmosphere. *Sargeant & Wilbur*

646. Analysis
Bulletin 130-I on methods for electroanalysis. Bibliography. *Eberbach Corp.*

647. Annealing
Booklet on burner for annealing and other uses where flame impingement is not permissible. *Bloom Engineering*

648. Annealing and Desanding
Article on furnace installation for simultaneous annealing, desanding and descaling of castings. *Sunbeam*

649. Annealing Furnaces
8-page illustrated booklet on continuous annealing furnaces. Schematic diagrams, photographs, and actual production data. *Drever Co.*

650. Atmosphere Furnace
Illustrated bulletin describes new controlled atmosphere furnace. *Industrial Heating Equipment Co.*

651. Atmosphere Furnaces
Information on mechanized batch-type atmosphere furnaces for gas cyaniding, gas carburizing, clean hardening or carbon restoration. *Dow Furnace*

652. Atmosphere Furnaces
Reprint on bright annealing of copper in atmosphere furnace. *Holcroft*

653. Austempering
Article on modified austempering of cylinder liners at Jacobs Aircraft Co., from "Tips and Trends". *Ajax Electric*

654. Automatic Rockwell
Bulletin on high-speed automatic Rockwell hardness tester for quantity production. After testing, pieces are automatically sorted into good, too soft, too hard. *Testing Equipment Co.*

655. Automotive Forgings
Folder shows 31 forged parts for auto industry. *Pittsburgh Forgings*

656. Bearing Failures
12-page bulletin 146 outlines basic steps for prevention of common babbitted bearing failures—choice of metal, pouring practice, in-service maintenance. *Federated Metals Div.*

660. Brazing
24-page bulletin 20 on advantages of Easy-Flo silver brazing alloy, with information about joint design and fast production methods. *Handy & Harman*

661. Brazing Alloys
Booklet explains uses of phos-copper and phos-silver extruded alloys for torch, furnace and resistance brazing of copper, brass and bronze. Also data on brazing flux. *Westinghouse Electric*

662. Brazing Titanium
Data sheet on use of a new flux for brazing titanium. *Handy & Harman*

663. Bright Annealing
Bulletin on conveyor furnace for bright annealing and brazing of stainless steel. *Sargeant & Wilbur*

664. Bronze
12-page technical bulletin on seven grades of bearing bronze. Six case histories. *American Crucible Products*

777. High Alloy Castings

Specific information for the users of alloys in high temperature and corrosive service is offered in "Heat Resistant and Corrosion Resistant Alloy Castings in Industry".* This new publication relates alloy composition and operating conditions for almost 200 specific applications. Most important is heat treating equipment with 72 illustrated examples (subdivisions: carburizing fixtures, conveyers, hearths, rails, rollers, salt pots, hot gas fans, muffles, radiant tubes, and 16 miscellaneous). More than a hundred examples cover chemical, petroleum and other process applications. Jet engine and power plant parts are dealt with in somewhat less detail.

The first section of text is devoted to heat resistant castings, with charts, tables, typical uses and recommended temperatures for each of the five groups of alloys. Corrosion resistant castings are compared in the second section, and, as in the first, the constant theme is serviceability in specific uses. The rest of the book is devoted to the illustrated applications, each picture accompanied by a statement on service temperature, alloy composition, size and an identification of the foundry that produced the casting.

Throughout the book, maximum use is made of the standard designations of the Alloy Casting Institute, and the Foreword urges adoption of the ACI terminology among users generally.

Concerned with a product that serves industry's most severe requirements, the book achieves a good balance of subject matter without omitting the all-important answer on which alloy for which service. It is difficult to imagine an industrial application not shown or suggested by the photographs.

*Published by The International Nickel Co., Inc. Copies are available at no charge to readers of Metal Progress who circle No. 777 on the literature request card, page 32B.

657. Bending
Presses for bending, forming, blanking, drawing and multipunching are described in catalog 2010. *Cleveland Crane & Engineering*

658. Beryllium Copper
Helpful engineering information contained in monthly beryllium copper technical bulletins. *Beryllium Corp.*

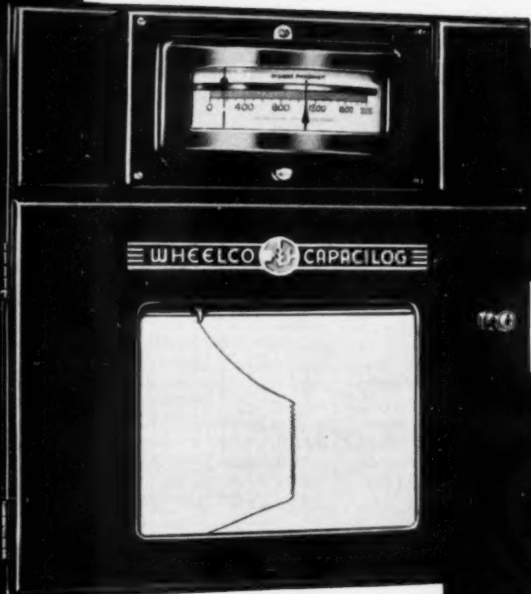
659. Black Coating
Technical bulletin on Parco Black finish, having high corrosion resistance on steel. *Parker Rust Proof*

665. Bronzes
Folder gives tables of properties (hardness, tensile, fabrication, physical) as well as uses and forms and other data on phosphor bronzes. *Chase Brass*

666. Buffing and Polishing
Catalog A-50 on fire-head rotary machine for automatic polishing and buffing of parts from $\frac{1}{16}$ to 12 in. diameter. *Hammond Machinery*

667. Burnishing
20-page bulletin on burnishing materials, finishing barrels. Six steel burnishing shapes explained. *Abbott Ball*

engineered simplicity



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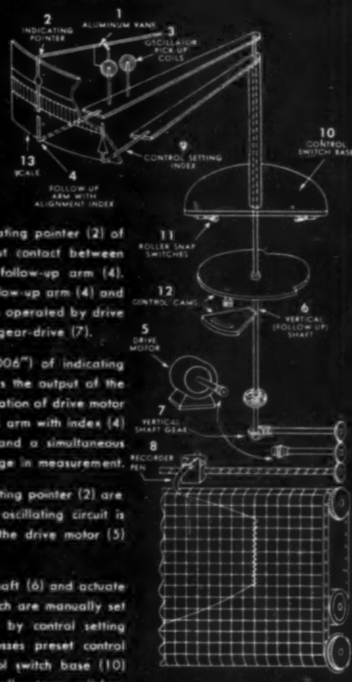
instantaneous "no contact" controlling

Single Point Electronic Strip Chart Recorder-Controller

Engineered simplicity gives operating accuracy and mechanical stamina to Capacilog Recorder-Controllers.

Elimination of mechanical clamping mechanism between indicating pointer and control unit allows instantaneous recording action. Design simplicity confines moving parts to a minimum; maintenance is easy, mechanical wear is negligible. An added convenience is the plug-in chassis for facilitating quick replacement or change-over.

Capacilog strip chart Recorders are available with either high or low temperature measuring systems for electrical or pneumatic control. Write for Bulletin C2-2.



The aluminum vane (1) mounted on indicating pointer (2) of measuring system is free to pass without contact between the oscillator coils (3) mounted on the follow-up arm (4). An Alignment Index is mounted on this follow-up arm (4) and is coupled to scriber mechanism which is operated by drive motor (5) through vertical shaft (6) and gear-drive (7).

An imperceptible deviation (.004" to .006") of indicating pointer (2) with respect to coils (3) alters the output of the oscillating circuit causing instantaneous rotation of drive motor (5) in proper direction to move follow-up arm with index (4) to coincide with indicating pointer (2), and a simultaneous movement of pen (8) to record the change in measurement.

When the Alignment Index (4) and indicating pointer (2) are in exact coincidence, the output of the oscillating circuit is balanced with the supply voltage, and the drive motor (5) does not rotate.

Control cams (12) rotate with vertical shaft (6) and actuate roller type snap action switches (11) which are manually set at the selected control level indicated by control setting index (9). When indicating pointer crosses preset control level, control action takes place. Control switch base (10) will accommodate a maximum of four roller type switches.

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668. Camera Microscope
6-page folder describes universal and compact metallograph with built-in camera. *Wm. J. Hacker*

669. Carbon and Graphite
20-page catalog on carbon and graphite applications in metallurgical and process fields. *National Carbon*

670. Carbon Control
Catalog T-623 describes the Microcarb control system that continuously measures the active carbon in the furnace atmosphere during heat treatment. *Leeds & Northrup Co.*

671. Carburizing Baths
Bulletin contains charts of relative case penetrations at various times and temperatures. Also replenishment chart for salt baths. *A. F. Holden Co.*

672. Case Hardening
Bulletin 159 describes standard rated batch furnaces for case hardening. *Surface Combustion*

673. Ceramic Coating
24-page book on ceramic coating as a means of conserving strategic metals and extending metal life at high temperatures. *Solar Aircraft*

674. Chromium Plating
"How to Chromium Plate 20 to 80% Faster" describes self-regulating high-speed bath. *United Chromium*

675. Chromium Stainless Steels
Folder on uses of chromium stainless steels; table of analyses and properties. *Lebanon Steel Foundry*

676. Cleaners
40-page catalog of cleaning and finishing chemicals, solutions, and reagents. *Globe Chemical*

677. Cleaning
6-page bulletin includes concentrations for various metal cleaning applications and a handy list of cleaners for general industrial use. *E. F. Houghton*

678. Cleaning
Bulletin 6521 on vapor degreaser. Drawings, specifications. *Randall Mfg.*

679. Cleaning and Buffing
24-page booklet describes origin and development of various metal cleaners and tripoli compositions. *Puritan Mfg.*

680. Cleaning and Finishing
16-page brochure on various cleaning processes, phosphating, aluminum brighteners and rust preventives. Reference chart included on six phosphating cycles. *Turco Products*

681. Cleaning and Finishing
Catalog A-653 on planning industrial finishing systems shows many installations of cleaning and pickling machines. *R. C. Mahon Co.*

682. Cleaning Equipment
Vapor degreaser described and diagramed in folder. Data on different models. *Topper Equipment*

683. Cleaning Machines
12-page bulletin on washing and drying machines; conveyor, cabinet, drum and vertical types. *Industrial Systems*

684. Cleaning Zinc
Bulletin on electrocleaner 505 for control of blistering and streaking on zinc-base die castings. *Diversey*

685. Coatings
Information on Bonderite coating which is resistant to corrosion and a good paint base. *Parker Rust Proof*

686. Coatings, Metal
High-vacuum evaporation of metals set forth in detail in 12-page booklet. *Distillation Products*

687. Cold Heading Brass Wire
"Cold Heading Extruded Brass and Copper Alloy Wire" booklet gives physical and fabrication properties, applications, weights per 1000 ft. and ft. per lb. *Chase Brass & Copper*

688. Combustion Control
20-page booklet presents combustion charts for various fuels and describes portable instrument which measures content of oxygen and combustibles simultaneously. *Cities Service Oil*

689. Combustion Equipment
Catalog 52 gives condensed pictorial review of oil and gas combustion equipment for production applications. 80 illustrations. *Hauck Mfg.*

690. Composite Castings
16-page brochure illustrates 50 applications of casting process for making bi-metallic components. *Al-Fin Div.*

691. Compressors
12-page data book 107-C gives engineering information on characteristics of turbo-compressors. 18 types of application described. *Spencer Turbine Co.*

692. Controlled Atmospheres
Bulletin on Dewpointer for reading of atmosphere in field and laboratory. Readily portable, operating on A.C. or enclosed battery. *Illinois Testing Labs.*

693. Controlled Atmospheres
24-page bulletin describes production problems with reference to dry atmospheres. *Pittsburgh Lectrodryer*

694. Copper Alloys
Article on refining secondary copper alloys deals with sequence of removal of Al, Mn, Si, P, Fe, Zn, and use of pure oxygen instead of air. *R. Lavin & Sons*

695. Copper Alloys
60-page book of technical information on copper and copper alloys. Six grades of copper and 33 copper alloys are included. *Revere Copper and Brass*

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Sure Spec Drill Rod is high grade tool steel . . . comes in manufacturer's standard sizes at low prices!

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WRITE TODAY to our nearest office shown below for a *comprehensive data book* detailing all the facts about Sure Spec drill rod, such as sizes, analysis, uses and treating. Also, at your request, one of our sales engineers will call to discuss your particular drill rod requirements and quote prices.

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696. Corrosion of Copper
24-page booklet B-36 discusses corrosive attack on copper and copper alloys. Tabulation of their relative corrosion resistance. *American Brass Co.*

697. Corrosion-Proof Cement
Bulletin gives corrosion resistance of four types of cement vs. 176 chemical solutions. *Atlas Mineral Products*

698. Corrosion Protection
Bulletin shows 24 applications of vapor wrap corrosion protection. *Angier*

699. Cutting Compounds
Data on cutting compounds for stainless and titanium. *Hangsterfer's Labs.*

700. Cutting Fluids
Circular slide rule simplifies dilution of cutting fluids. For tanks of 1 to 100 gal. *D. A. Stuart Oil Co.*

701. Cutting Oil
80 pages of factual data on more than 50 typical metalworking jobs in "Cutting and Grinding Facts". *Sun Oil*

702. Cutting Oil
New pamphlet, "Gulf Lasupar Cutting Oil", on sulphurized oil which can be used on stainless steel and more easily machined alloys. *Gulf Oil Corp.*

703. Deburring
Bulletin on deburring and other barrel finishing. *Magnus Chemical*

704. Demineralizer
Bulletin on ion-exchange demineralizer for low-cost purification of water for plating. *Industrial Filter & Pump*

705. Descaling Process
8-page bulletin on sodium hydride descaling process for ferrous and nonferrous metals. Treating cycle, chemistry, equipment design. *Du Pont*

706. Die-Casting Machines
Illustrated booklet giving specifications, application data and full explanations of two new production advantages on company's line of die-casting machines. *Lake Erie Engineering*

707. Dial Gages
36-page catalog of dial gages of all types. *Nilsson Gage*

708. Dimensioning
40-page "Practical Dimensioning" tells how to avoid errors in the dimensioning of drawings. *Gisholt Machine*

709. Dipping Baskets
Catalog B-7 illustrates and describes various kinds of dipping baskets and other processing carriers. *Rolock, Inc.*

710. Ductile Iron
New list of publications available on advantages and properties of ductile iron, along with special applications and 100 authorized foundry sources now producing it. *International Nickel*

711. Ductile Iron
Bulletin compares ductile iron with gray iron, malleable iron and cast steel. Eight examples where ductile iron is profitable. *American Brake Shoe*

712. Electric Furnaces
Bulletin 473 on automatic melting machine for ferrous and nonferrous alloys. *Detroit Electric Furnace*

713. Electro-Clad Tubing
Bulletin on internally nickel plated steel tubing. *Bart Mfg.*

714. Electrodes
Chart of typical weld metal analyses and Arcos electrodes. *Arcos Corp.*

715. Electromagnet
Bulletin on multipurpose high-flux-density electromagnet for metal research. *Arthur D. Little, Inc.*

716. Electroplating Aluminum
15-page Bulletin 7 on recommended practices for plating aluminum alloys with Cr, Ni, Cu, Ag, Au, brass. *Alcoa*

717. Electropolisher
Bulletin on theory and practice of electrolytic polishing. Description of electropolisher. *Buehler, Ltd.*

718. Extrusion of Aluminum
Bulletin 340-A on aluminum extrusion process and presses of 500 to 5000 tons capacity. *Watson-Stillman*

719. Fasteners
22-page handbook of industrial fasteners. *Southco*

720. Ferro-Alloys
Book describes over 50 metals and alloys produced by company. *Electro Metallurgical Co.*

721. Finishes
Folder gives characteristics and uses of chromate conversion coatings on nonferrous metals. *Allied Research*

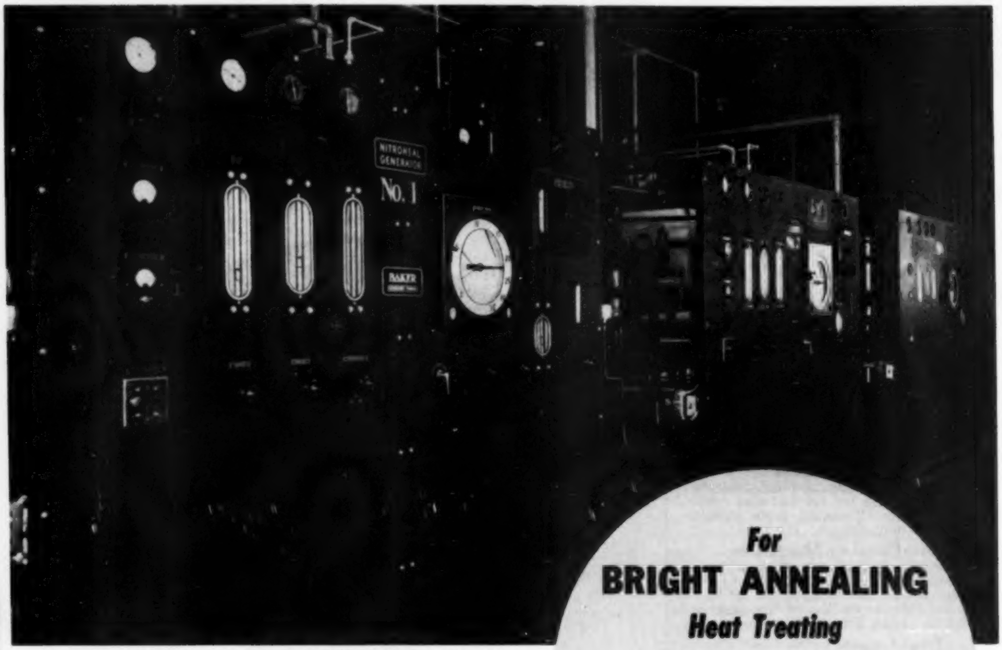
722. Finishes for Aluminum
8-page reprint on surface preparation, electrochemical, organic, ceramic, mechanical and chemical finishes for aluminum alloys. *Alcoa*

723. Finishing
22-page book gives facts and figures on barrel finishing, tells how single-unit installation may yield savings up to 95% on various parts. *Almco Div.*

724. Finishing
Six bulletins describing finishing compounds for stainless steel, aluminum, and other metals. *Apothecaries Hall*

725. Finishing
Technical bulletin describes Aluminux, a new etching compound that eliminates cement-like scale formation on tank and coils. *Diversey Corp.*

NITRONEAL GAS



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- **NO OPERATING PERSONNEL REQUIRED**
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% HYDROGEN	.25	1.0	3.0	6.0	20.0	25.0	30.0
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726. Flow Meters
12-page catalog 40 describes variable-area flow meters having precise tapered metal metering tubes and designed for both high temperature and high pressure. *Fischer & Porter Co.*

727. Flux, Aluminum Melting
Data sheet on four fluxes for degassing and purifying aluminum alloys. *Atlantic Chemicals & Metals*

728. Forging Presses
Catalog 42 gives complete specifications for high-speed forging presses in capacities from 300 to 4000 tons. *Bliss*

729. Forgings
20-page Catalog 51 on various types of forgings, their strength and related data. Section on lifting devices. Tables and drawings. *Merrill Bros.*

730. Forming Magnesium
Article covers bending, spinning, stretch forming, deep drawing of magnesium sheet. From "Magazine of Magnesium". *Brooks & Perkins, Inc.*

731. Foundry Coatings
Brochure on foundry practices as related to colloidal graphite for mold washes, pattern coatings, core coatings, chill coatings. *Acheson Colloids*

732. Foundry Practice
Article discusses gates and risers with special reference to nonferrous practice. *R. Lavin & Sons*

733. Furnaces
Bulletin SC-156 on direct-fired furnaces for routine jobs. Applications, performance data. *Surface Combustion*

734. Furnaces
High temperature furnaces for temperatures up to 2000° F. are described in leaflet. *Carl-Mayer Corp.*

735. Furnaces
40-page booklet, "Harnessing Heat", describes types of gas and electric furnaces and their applications. Section on the four basic types of protective atmospheres and a glossary of heat treating terms. *Westinghouse*

736. Furnaces
44-page Catalog 112, well illustrated, features furnaces for hardening, tempering, carbonitriding, forge heating, sintering, annealing and tool heat treating. Also atmosphere generators and ammonia dissociators. *C. I. Hayes*

737. Furnaces
Catalog on electric furnaces for tool room and general-purpose heat treating; also 600° F. ovens. *Cooley Electric*

738. Furnaces
Catalog on high-speed gas furnaces for heat treating high-carbon and alloy steels; also pot furnaces for salt, cyanide and lead hardening. *Hones, Inc.*

739. Furnaces
12-page bulletin on conveyor furnace, radiant tube gas heated, oil or electrically heated. *Electric Furnace Co.*

740. Furnaces, Atmosphere
Bulletin F-1 on versatile, controlled-atmosphere furnace for all steels from high carbon to high speed in range 1200 to 2800° F. *Delaware Tool Steel*

741. Furnace Brazing
8-page article describes electric furnace brazing of ordnance assemblies at Southern Electro-Plating Co. *Sunbeam*

742. Furnace Controls
28-page catalog 51-1 on furnace and oven controls lists prices and illustrates variety of instruments such as temperature controllers, recorders, indicators and valves. *Minneapolis-Honeywell*

743. Furnace Fixtures
16-page Catalog 16 on baskets, trays, fixtures, retorts and carburizing boxes for heat treating and quenching; 66 designs. *Stanwood Corp.*

744. Furnaces, Laboratory
26-page "Construction of Laboratory Furnaces" contains many diagrams, charts, tables, and information on how to construct furnaces. *Norton Co.*

745. Furnace Maintenance
"Maintenance Guide for Electric Heat Treating Furnaces" describes preventive program. *Hevi Duty Electric*

746. Furnaces, Rotary Hearth
Folder giving drawings, dimensions, capacity, Btu required for drawing, annealing, forging. *Gas Machinery*

747. Furnaces, Small Tool
Folder describes complete set-up for heat treatment of small tools, including draw furnace, quench tank and high temperature furnace. *Waltz Furnace*

748. Galvanic Coating
8-page booklet 452 on Galvanite, a galvanic coating applied with a brush. *Galvanite Corp.*

749. Gas-Air Mixers
8-page bulletin 5-C gives engineering data on selecting and matching burners and mixers. Master table enables selection of mixer for any type of fuel gas. *Bryant Industrial Div.*

750. Gas Analysis
Theory of gas analysis, procedures in various analyses and maintenance and operation of equipment in 60-page manual. *Fisher Scientific*

751. Gas Burner Nozzles
Catalog 804-C gives capacities and other data on 19 sizes of straight and elbow-type nozzles. Spark and gas pilot ignition also explained. *Hauck Mfg.*

752. Gas Carburizing
Bulletin 1211A on uniform gas carburizing in rotary furnaces. *American Gas Furnace*

753. Gas Flow Meter
Bulletin 52-1017-37 on gas flow meter for furnace installations. *Hays Corp.*

754. Gas-Oil Burner
Bulletin on combination gas and oil burner with high rate of combustion. *Ra-Diant Heat Refractories Sales*

755. Gear Hardening
Folder on application of induction heating to high-production hardening of gears. *Westinghouse Electric Corp.*

756. Graphitic Tool Steels
48-page booklet on heat treating data, properties and 40 specific applications of graphitic tool steel. *Timken*

757. Grinders
Catalog No. 75 describes bench and floor-type wheel grinders, polishing lathes and backstands of various sizes and capacities. *Hammond Machinery*

758. Grinding Titanium
Article on grinding wheels and techniques for titanium. *Norton Co.*

759. Hand Pyrometer
Data sheet GEC-836 on hand pyrometer with scale ranges of 0 to 500 and 0 to 1500° F. *General Electric*

760. Hard Facing
12-page Manual 77 on Colmonoy Alloys for hard facing. Extensive list of applications and alloy recommended for each. *Wall Colmonoy*

761. Hard-Facing Alloys
"Hard-Facing Materials Data" summarizes hardfacing alloys, giving composition, properties, uses and forms. *Haynes Stellite*

762. Hardening Stainless
24-page "Story of Malcomizing" describes surface hardening of stainless steels. Includes case histories. *Lindberg Steel Treating Co.*

763. Hardness Numbers
Pocket-size table of Brinell hardness numbers, incorporating other tabular information of importance to the metallurgist, inspector and engineer. *Steel City Testing Machines, Inc.*

764. Hardness Tester
Bulletin on Rockwell-type instrument having optical system to give Rockwell readings directly on a dial. *Opplem Co.*

765. Hardness Tester
Circular on portable hardness tester in sizes for work 1 to 6 inches round and flat. *Ames Precision*

766. Hardness Tester
4-page bulletin on Brinell hardness tester weighing 26 lbs. for portable and stationary use. *Andrew King*

767. Hardness Tester
Bulletin DH-114 contains full information on Tukon hardness testers for use in research and industrial testing of metallic and nonmetallic materials. *Wilson Mechanical Instrument*

768. Heat-Resisting Alloy
Pyrasteel bulletin describes chromium-nickel-silicon alloy for service economy in resisting oxidation and corrosion to 2000° F. *Chicago Steel Foundry*

769. Heating Elements
24-page Bulletin H on electric heating elements. Extensive tabular data on physical and electrical specifications for various sizes. *Globar Div.*

770. Heat Treating
Booklet describes complete diversified facilities for heat treating steel, aluminum and magnesium. *Pearson Industrial Steel Treating Co.*

771. Heat Treating
Ipsenlab periodic sheets show case histories on bright hardening, annealing and carburizing. *Ipsen Industries*

772. Heat Treating Baskets
Data sheet on metal baskets for heat treating, quenching, nitriding, pickling and galvanizing. *Rose Iron Works*

773. Heat Treating Fixtures
Catalog B-8 describes and shows 75 custom-built fabricated alloy heat treating accessories. *Rolock*

774. Heat Treating Furnaces
Bulletin on gas, oil and electric furnaces of box and pot types for heat treating. *Dempsey Industrial Furnace*

775. Heating of Plating Baths
Illustrated bulletin on unit heat exchangers designed to maintain working temperature of nickel plating solutions by continued heating or cooling in the same unit. *Industrial Filter & Pump*

776. Heat Treating of Tools
Information on "Sure-Wear" process for heat treating high-speed cutting tools. *LR Heat Treating Co.*

777. High Alloy Castings
See review on page 21.

778. High-Temperature Steels
87-page spiral-bound book discusses behavior of steels at elevated temperature, factors affecting high-temperature properties. 45 pages of tabular and graphical data on tensile, creep and rupture properties of 21 grades of high-temperature steel. *United States Steel*

779. Identifying Alloys
Booklet of procedures for rapid identification of more than 125 metals and alloys. *International Nickel*

780. Immersion Heating
Bulletin 1E-11 gives complete details on how immersion pots save time in melting soft metals. *C. M. Kemp Mfg.*

781. Impregnation of Castings
Bulletin on sealants and methods to correct microporosity in ferrous and nonferrous castings. *Polyplastex*

782. Impregnation of Castings
Literature on new impregnating equipment for elimination of porosity in ferrous and nonferrous castings. *Metallizing Co. of America*

783. Induction Heat Control
Sheet 83 on miniature radiation-detecting temperature-measuring device for flame hardening and induction heating. *Minneapolis-Honeywell*

784. Induction Heating
Data folder on megacycle tube-type machines for soldering, brazing, hardening. *Sherman Industrial Electronics*

785. Induction Heating
12-page bulletin on equipment for induction heating. Describes requirements for hardening, brazing, and annealing at 1000, 3000, and 10,000 cycles. *General Electric*

786. Industrial Photography
Book entitled "Functional Photography in Industry" describes processes and techniques. *Eastman Kodak*

787. Inert Gas Welding
Heliwelding, inert-gas-shielded arc-welding process for all-position welding of aluminum, magnesium, stainless steel, brass and copper, in ADC-709, Catalog 9 *Air Reduction Sales*

788. Inspection
20-page bulletin on high-speed automatic gaging and sorting; 43 applications are illustrated. *Federal Products*

789. Inspection Stamps
16-page catalog of letter, figure and inspection stamps, marking dies and numbering machines. *Dickey-Grabler*

790. Instruments
28-page catalog No. 5000 describes instruments, control devices and related components. *Minneapolis-Honeywell*

791. Liquid Carburizing
New technical bulletin describes use and operation of water-soluble liquid carburizing baths. *Park Chemical*

792. Lithium in Copper
Data available on effect of lithium on electrical conductivity and porosity of copper and its alloys. *Metalloy Corp.*

793. Lockseam Tubing
Blueprint of size ranges of round or oval lockseam tubing in a wide range of metals. *H & H Tube and Mfg.*

794. Low-Temperature Tests
Bulletin MC-1 on cryostat that maintains test chamber from 70° F. to within 2° of absolute zero. *Arthur D. Little*

795. Lubricant
40-page booklet on Moly-sulphide lubricant gives case histories for 154 different uses. *Climax Molybdenum*

796. Machining Alloy Steels
24-page bulletin on economical combination of microstructure, tool form, cutting speed and feed for each machining operation. *International Nickel*

797. Machining Titanium
Article on recommended practices for machining titanium, from first issue of "Titanium Review". *Rem-Cru Titanium*

798. Magnetic Alloys
20-page bulletin on the more important "magnetically soft" iron-nickel alloys. *International Nickel*

799. Magnesium in Automobile
Article on automotive uses for magnesium, from "Topics". *Dow Chemical*

800. Magnesium in B-36
Article on service experience with magnesium in B-36 bomber. *Dow Chemical*

801. Magnesium Melting
Bulletin on use of fabricated steel crucibles in melting of magnesium alloys. *American Tank & Fabricating*

802. Magnesium Welding
Reprint describes an investigation to evaluate inert-gas-shielded metal-arc welding of magnesium. *Air Reduction*

803. Mechanical Cleaning
76-page catalog 210 simplifies selection of power brushes; contains numerous illustrations of various types of brushes in operation. *Osborn Mfg.*

804. Mechanical Cleaning
30-page booklet describes 12 case histories of how brushes were used for cleaning welds, stainless sheets, hot cast iron, automotive parts, brass fixtures. *Pittsburgh Plate Glass, Brush Div.*

805. Melting Furnaces
8-page Bulletin 560 describes stationary and tilting types of two-chamber melting furnaces. Applications to sand, permanent mold, centrifugal and die casting. *Lindberg Engineering*

806. Melting Pots
Bulletin 201-B on alloy cast iron melting pots for use in aluminum foundries, die-casting plants and smelting works. *American Car and Foundry*

807. Metal Analysis
Brochure on Quantometer, which furnishes pen-and-ink records of quantitative spectrochemical analyses, with extra copies. *Applied Research Labs.*

808. Metal Conveyor Belts
44-page catalog describes metal belts for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

809. Metallograph
Revision of catalog includes the new metallograph with polarizing and phase attachments. *American Optical*

810. Metals Comparator
Bulletin GEC-566 on electronic quality control equipment which indicates

hardness variations by magnetic measurement. *General Electric*

811. Microscopes
22-page catalog describes microscopes featuring ball bearings and rollers throughout the focusing system and a low-position fine adjustment, providing comfortable operation. *Bausch & Lomb*

812. Multiport Gas Burner
8-page Bulletin 1009 on screen burner for furnace or open firing. *Selas*

813. Nickel Plating
44-page book, "Practical Nickel Plating", gives detailed information for the designer and specifying engineer. 40 illustrations, tables and charts; 41 references. *International Nickel*

814. Nonferrous Melting
12-page bulletin on eight types of gas furnaces for melting nonferrous metals. *Bellevue Industrial Furnace*

815. Nonferrous Metals
"Metal of the Month" letters include market trends and helpful data. *Belmont Smelting & Refining*

816. Nonferrous Tubing
Bulletin on seamless, brazed and lockseam tubing in brass and copper. *H & H Tube and Mfg.*

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Folder on tubular products in copper, brass and aluminum, including finned and corrugated tubing. *Fromson Orban*

818. Oil Firing
Catalog 715 explains an easy means of standby oil firing for plants having seasonal shortages of gas. *Hauck Mfg.*

819. Quench Conveyor
8-page bulletin on continuous quench tank conveyor and other production equipment. *The Klaas Machine & Mfg.*

820. Quenching
"Handbook on Quenching" gives complete information. *E. F. Houghton & Co.*

821. Parts Dryer
Bulletin gives specifications and drawings of centrifugal dryer for small parts. *Nobles Engineering and Mfg.*

822. Pearlitic Malleable
Folder 12 on properties of pearlitic malleable iron. *Belle City Malleable Iron*

823. Peening
Catalog describes selection and use of shot and grit for cleaning and peening. *Cleveland Metal Abrasive*

824. Peening
Bulletin on use of cut wire shot for peening and cleaning. *Park Chemical*

825. Photomicrography
Full information on Aristophot camera with Ortholux research microscope for photomicrography. *E. Leitz, Inc.*

826. Pickling
Bulletin on heating and agitating pickling solutions. *Ozark-Mahoning*

827. Pickling Acid Inhibitor
Selection chart tabulates properties and uses of 15 types of Rodine pickling acid inhibitor. *American Chemical Paint*

828. Plating Control
Data on instruments for control of plating solutions and on other plating equipment. *Demott Industries*

829. Plating Generators
Catalog describes motor-generator set for electroplating, anodizing, or electropolishing. *Columbia Electric*

830. Plating Racks
8-page booklet offers data on a plating rack designed to make the spline section or body of the plating rack a permanent tool. *National Rack*

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Bulletin on selenium rectifiers for plating and anodizing. *Wesley Block*

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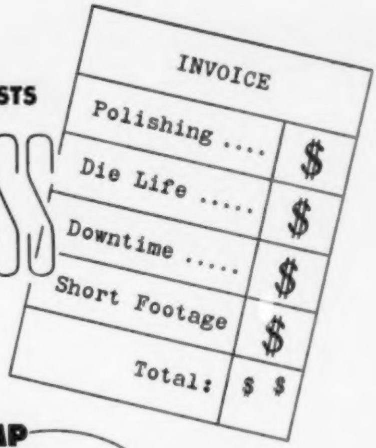

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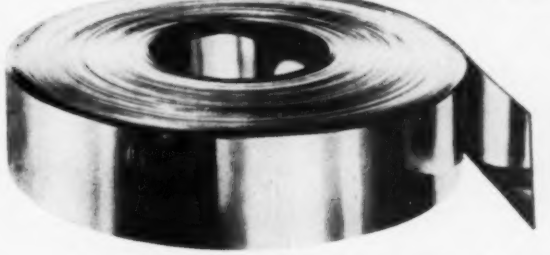

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16-page bulletin on electroplating Pb, Sn, Fe, Cu, Ni, Cd, and In from fluoborate solutions. *General Chemical*

833. Plating Tank Liners
Corrosion data on Koroseal tank linings in contact with plating baths and other corrosive solutions. *Metalweld*

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6-page bulletin on application of single-spindle machine in polishing formed parts having either plane or curved surfaces. *Vanott Machine Corp.*

835. Polishing
Catalog A-60 on polishing lathes up to 3600 rpm. *Hammond Machinery*

836. Powder Metallurgy
Information on sponge iron powder. *Ekstrand & Tholand*

837. Precise Length Measure
Bulletin DM 1250 on electromechanical device for measurement of displacement, vibration or movement to 0.0001 in. *Electro Products Labs.*

838. Precision Casting
8-page bulletin on investment castings of ferrous and nonferrous alloys. *Engineered Precision Casting*

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12-page booklet, "Pour Yourself an Assembly", describes wide range of applications and alloys for precision casting. *Precision Metalsmiths*

840. Precision Strip
Thin-gage and clad metals, as well as precious metal strips, wire and powder, which are still available, are listed in Bulletin 9-B. *American Silver*

841. Pre-Plated Metals
16-page fabrication handbook on preplated metals, ferrous and nonferrous. *American Nickeloid*

842. Program Controllers
Bulletins 1501 and 1502 describe, respectively, strip-chart and cam-operated program controllers for automatic regulation of time-temperature schedules. *Minneapolis-Honeywell*

843. Protection for Aluminum
Folder on Alodine for protection of painted or unpainted aluminum. *American Chemical Paint*

844. Pyrometers
Information on Xactemp pyrometers; also Xactline straight-line temperature control for use with any standard controller. *Claud S. Gordon Co.*

845. Pyrometer Supplies
Buyer's Guide for pyrometer supplies, No. 100-4. *Minneapolis-Honeywell*

846. Rapid Carbon Analysis
Literature on complete line of rapid carbon analyzers for steel, cast iron, pig iron, coal, coke and oil. *Laboratory Equipment Corp.*

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34-page book on X-ray applications features radiography of castings and weldments. *X-Ray Dept., Gen. Electric*

848. Radiography
Bulletin 400-310 on self-contained X-ray unit for mass production inspection of parts. *Westinghouse*

849. Recording Potentiometer
14-page folder on simplified single-point recorder of the potentiometer type. *Weston Electrical Instrument*

850. Recirculating Furnaces
16-page Bulletin 81 describes and illustrates heat treating furnaces for ferrous and nonferrous parts and other heat treat equipment. *Despatch Oven*

851. Refractories
12-page brochure on products for casting special refractory shapes and for gunning and troweling applications, for services to 3000° F. *Johns-Manville*

852. Refractories
20-page booklet gives technical information on super refractories. Charts, tables and application data. *Refractories Div., Carborundum Co.*

853. Resistance Welding
12-page bulletin SP351 on nine basic types of resistance welders. *Federal Machine and Welder*

854. Reverse-Current Cleaner
Bulletin on electrocleaner 12 for steel, copper and brass with either reverse or direct current. *Diversey*

855. Rolling Mills
Folder on 3x5 in. rolling mills for flat stock and wire. *Stanat Mfg.*

856. Roll-Over Furnace
Bulletin on mechanically-operated induction furnace for precision casting. *Ajax Electrothermic*

857. Safety Valves
Bulletin 400 describes safety valves for instantaneously shutting off fuel in case of power failure to some essential unit. *Western Products*

858. Salt Bath Furnace
Bulletin 123-B on submerged-electrode salt bath furnace for 10 heat treating applications in range 1100 to 2400° F. *Ajax Electric Co.*

859. Salt Spray Testing
Bulletin on lucite salt spray testing cabinet. *Singleton Co.*

860. Saws
Circular saw blades describ
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Motch & Merryweather

861. Set Screws
20-page catalog and referen
on set screws. *Set Screw & Mf*

862. Shell Molding
Data sheet on new synthetic
bonding shell molds. *Borden C*

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Cooper Alloy Foundry

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Bulletin B-211 on junior-size
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870. Springs Tester
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871. Stabilized Stainles
Bulletin 144 on Type 321
tubing. Condensed data on
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24-page bulletin 17 on mechanical applications of steel tubing. Many uses illustrated. *National Tube Div.*

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Equipment described for feeding and straightening coil stock for stamping, blanking or shearing. *F. J. Littell*

877. Straightening Wire
Bulletin 52-AA describes straightening machine for wire in size range from $\frac{1}{16}$ to 1 in. diameter, at speeds up to 200 ft. per min. *Medart Co.*

878. Subzero Freezer
4-page folder on portable freezer, 110-volt a.c., operating to $-180°$ F., for shrink fitting, hardening, stabilizing and testing. *Webber Appliance*

879. Subzero Thermometer
Information on recording thermometer for as low as $-200°$ F. *Dickson*

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Bulletin 40 describes device to measure surface electrical resistance as criterion for effectiveness of a cleaning process. *Weltronic*

881. Surface Grinding
54-page guidebook on use of disk grinders for grinding flat surfaces. *Gardner Machine*

882. Surface Temperatures
Pyrocon bulletin on hand-held thermocouple-type instrument for measuring and indicating surface temperatures at exact locations. *Illinois Testing Labs.*

883. Temperature Control
36-page bulletin P 1245 on new electronic instruments for recording and indicating variables. *Bristol Co.*

884. Testing
Booklet on Reflectoscope tells how ultrasonic vibrations penetrate up to 24 feet to "see" internal defects and fatigue cracks. *Sperry Products*

885. Testing Machines
30-page catalog on screw power universal testing machines and accessories. Details of construction and specifications. *American Machine & Metals*

886. Testing Machines
8-page folder on Amsler machines for tests in tension, compression, torsion, shear, fatigue, bending and ductility. *A. I. Buehler*

887. Thermocouples
36-page Bulletin 235-4 describes various types of thermocouples, extension wire and other accessories. *Foxboro*

888. Tin
24-page book on production, consumption, uses of tin. *Malayan Tin Bureau*

889. Titanium
30-page data book on properties of commercially pure and alloy titanium, melting, forging and rolling. 16 charts and micros; 4 hardness conversion curves for titanium. *Republic Steel*

890. Tool Room Furnaces
Bulletin 10-T describes twelve types of gas-fired furnace for tool room work. *Bellevue Industrial Furnace*

891. Tool Steel
Bulletin on general-purpose air hardening 5% Cr tool and die steel. *Ryerson*

892. Tool Steel
"How to Get Better Tool and Die Performance" describes the matched set method for selecting the right tool steel for production. *Carpenter Steel*

893. Tool Steel Selector
Twist the dial of the 9-in. circular selector and read off the tool steel for your application. *Crucible Steel*

894. Tool Steel Selector
Selector for general and heat treating data on nondeforming, water hardening, shock-resistant, hot work, high speed tool and hollow die steels. *A. Milne*

895. Tubing
Bulletin 32 on analyses available, production limits, commercial tolerances, temper designations of seamless and weldrawn tubing. *Superior Tube*

896. Tubing
Technical discussion of fabrication and forging of steel tubing is given in Handbook F-3. *Ohio Seamless Tube Co.*

897. Ultrasonic Cleaning
Bulletin GEA-5669 on equipment which converts electrical energy to high-frequency mechanical vibration for cleaning. *General Electric*

898. Vacuum Metallurgy
Bulletin gives résumé of vacuum metallurgical operations and research and development facilities and services available. *National Research Corp.*

899. Vanadium Recovery
Six-page article, "Recovery of Vanadium and Other Alloys in the Acid Electric Furnace". *Vanadium Corp.*

900. Vapor Degreasing
Pamphlet on properties and use of trichlorethylene. *Niagara Alkali*

901. Volt-Ammeter
Folder on clamp-type, hand size instrument for use on a.c. to 600 amp., 600 v. *Columbia Electric Mfg.*

902. Water Purity
Folder on device for testing purity of water and controlling flow. *Barnstead*

903. Welding Armor Plate
Booklet discusses new low-hydrogen ferritic electrodes for welding armored ships and tanks. *Arcos Corp.*

904. Welding and Cutting
64-page catalog of welding and cutting equipment, supplies, and accessories. *Southern Oxygen Co.*

905. Welding Low-Alloy Steel
12-page booklet guides users of low-alloy, low-hydrogen electrodes. *Arcos*

906. Welding Nickel Alloys
New 44-page book on fusion welding of nickel and high-nickel alloys. Illustrated and containing more than 30 tables. *International Nickel*

907. Welding With Bronze
Reprint describes techniques and choice of bronze electrodes for welding various copper, steel and cast iron sub-assemblies. *Ampco Metal*

908. Wire Fabrication
16-page handbook on applications and fabrication of wire. Engineering data, forming methods, 12 case histories. *E. H. Titchener & Co.*

909. Wire, Nonferrous
Folder gives wire gage and footage chart and data on beryllium copper, phosphor bronze, nickel, silver, brass and aluminum wire. *Little Falls Alloys*

910. Wire Straightening
Bulletin 52-C describes precision machine for straightening small wire with extreme accuracy. Applies to round wire 0.007 to 0.125 in. diameter of ferrous or nonferrous metal. *Medart Co.*

911. X-Ray Equipment
New catalog, "Industrial X-Ray Accessories", provides complete listing of this equipment, including chemicals, dark-room accessories, filing equipment, processing tanks, dryers and radiation instruments. *Picker X-Ray*

912. Zinc Analysis
Article on spectrographic analysis of zinc die-casting alloys, from News Letter. *Applied Research Labs.*

913. Zinc Die Castings
Folder on small parts applicable to production by die casting. *Dollin*

914. Zirconium and Titanium
16-page bulletin, "The Hydrimet Process", describes zirconium and titanium metal and hydride, and other metallurgical hydrides. *Metal Hydrides*

915. Zirconium Metal
26-page booklet gives physical, mechanical and chemical properties, present and potential uses, supply and prices of zirconium. *Titanium Alloy Mfg.*

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Title ______________________

Company ______________________

Address ______________________

City and State ______________________

Postcard must be mailed prior to Dec. 1, 1952.
Students should write direct to manufacturers.

Banish the "Bite"

ON PICKLING AND PLATING EQUIPMENT

with these NATIONAL (TRADE-MARK) CARBON AND GRAPHITE AND KARBATE (BRAND) IMPERVIOUS GRAPHITE PRODUCTS

Pickling and tinning are messy, expensive – and *necessary.* However, you can *greatly reduce* equipment maintenance costs and improve plant housekeeping by making full use of these National Carbon products wherever service is dirty and tough. As is well known by manufacturers of your pickling and plating *solutions*, only carbon and graphite and impervious graphite withstand the "bite" of so wide a range of corrosive chemicals.

HERE'S WHERE THEY'RE USED:

STAINLESS PICKLING

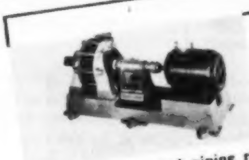
Carbon brick tank linings with "Karbate" Plate-Type Heat Exchangers and drain lines offer powerful resistance to nitric-hydrofluoric solutions.

ELECTROLYTIC PLATING

Graphite Anodes, either alone or in combination with dissolving-type anodes, are non-contaminating and long lasting.

Various immersion-type and shell-and-tube type "Karbate" Heat Exchangers are available to suit capacity requirements.

CARBON STEEL PICKLING



"Karbate" pumps and piping resist sulphuric and hydrochloric acid attack . . . protect solution from contamination.

"Karbate" Shell-and-Tube Heat Exchangers are often most economical where more than 50 square feet of heat transfer surface is required.

Graphite Tank Rolls provide an ideal combination of good electrical conductivity and resistance to acid attack in electrolytic pickling operations.

The terms "Karbate" and "National" are registered trade-marks of Union Carbide and Carbon Corporation

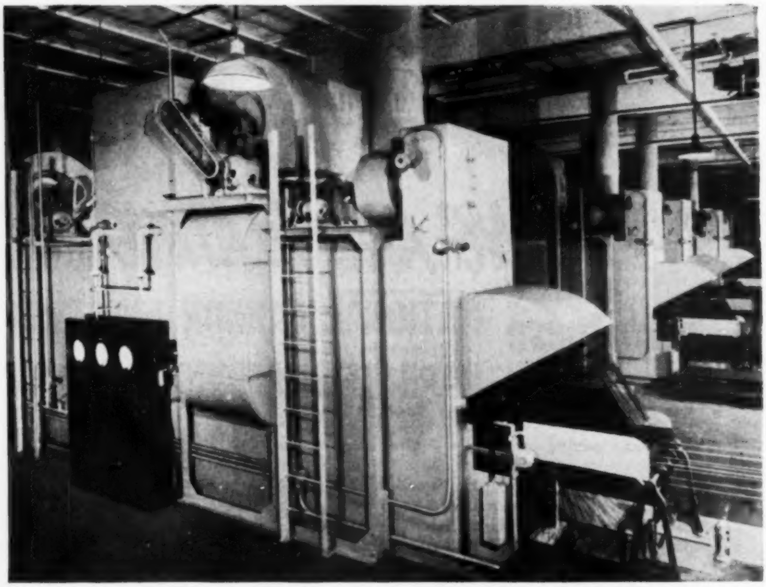
WRITE FOR CATALOG SECTION—S-5005

NATIONAL CARBON COMPANY
A Division of Union Carbide and Carbon Corporation
30 East 42nd Street, New York 17, New York

District Sales Offices: Atlanta, Chicago, Dallas, Kansas City, New York, Pittsburgh, San Francisco
IN CANADA: National Carbon Limited, Montreal, Toronto, Winnipeg

OTHER NATIONAL CARBON PRODUCTS

BLAST FURNACE LININGS • BRICK • CINDER NOTCH LINERS • CINDER NOTCH PLUGS • SKIMMER BLOCKS • SPLASH PLATES • RUNOUT TROUGH LINERS • MOLD PLUGS • TANK HEATERS



Above are a few of the 26 Young Bros. lithographic ovens at Crown Cork & Seal's Baltimore plant. Each oven is controlled by three Brown recording thermometers.

Ovens *by* Young Bros... Controls *by* Brown... *boost production at* Crown Cork & Seal

THE NEW lithographing department of Crown Cork & Seal Co., Baltimore, incorporates the most up-to-date facilities for economical, high-speed production of bottle closures. Typical of the modern equipment in this plant is a battery of 26 ovens, manufactured by Young Brothers Company. These ovens are used to bake both inks and coatings applied to metal sheets.

The baking temperature must be accurately controlled through the entire cycle, and for a wide variety of colors and materials.

Three heating zones are used, and each of the large burners is controlled with a Brown air-operated recording thermometer. The recorder charts show that the oven air temperature is held to within plus or minus *one degree* Fahrenheit of the control set point. No small part of the credit for this performance goes to the Honeywell control valves which regulate fuel to each furnace zone. By accurately carrying out the direction of the controllers, they supply the final measure of accuracy and responsiveness essential to close control. In addition, each zone is protected in the event of flame failure by a Honeywell *Protectoglo* combustion safeguard.

Your local Honeywell engineer will be glad to discuss how your furnaces and ovens can profit by modern instrumentation. Call him today . . . he is as near as your phone.

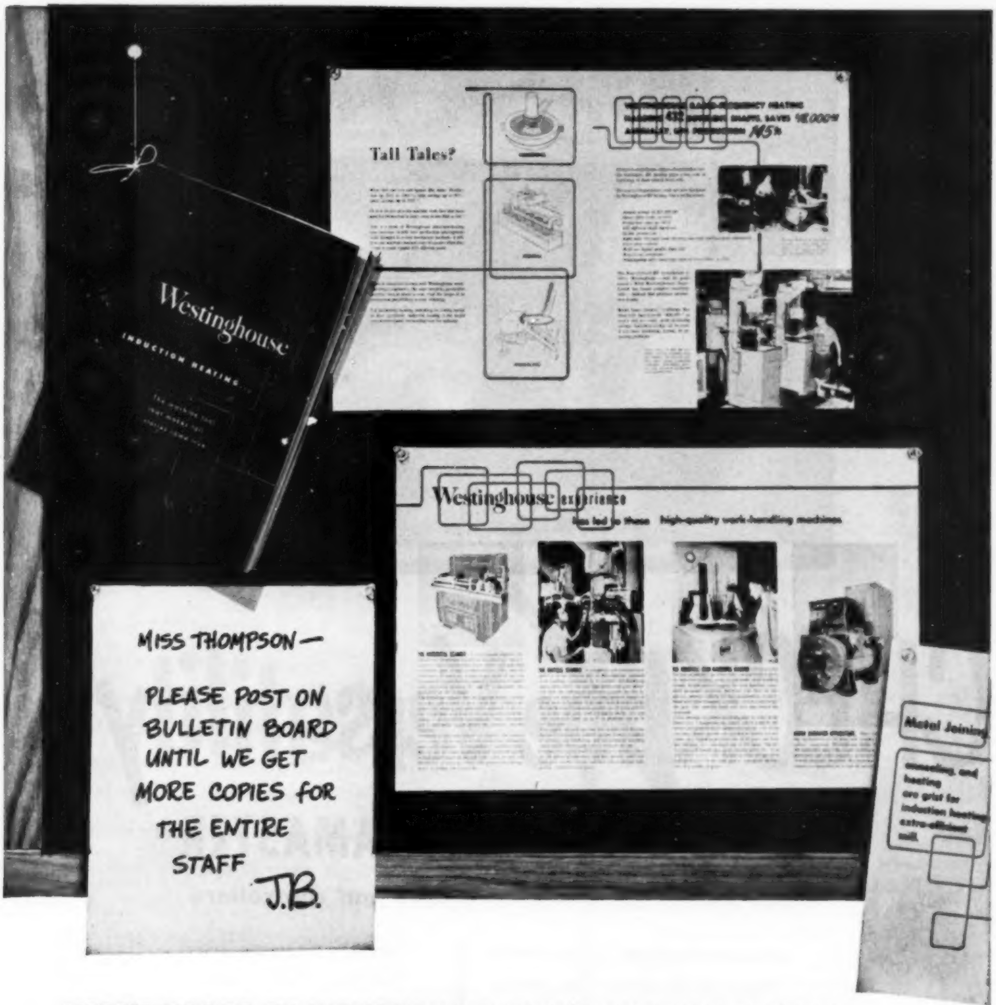
MINNEAPOLIS-HONEYWELL REGULATOR Co., *Industrial Division*, 4503 Wayne Ave., Philadelphia 44, Pa.

MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS

First in Controls

● ***Important Reference Data***

Write for Catalog No. 51-1, "Furnace and Oven Controls."



HERE'S PROOF OF INDUCTION HEATING'S AMAZING RECORD—

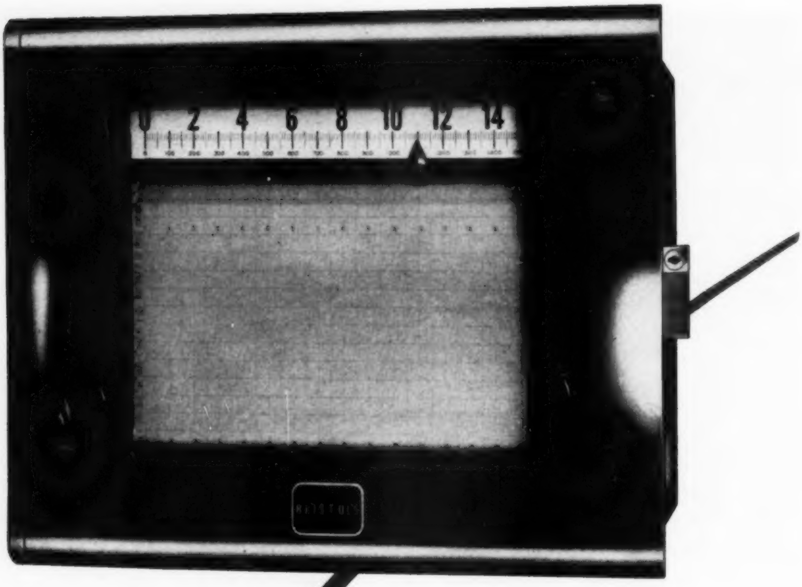
Actual case histories of hardening, brazing, soldering, and annealing installations show how the RF process has meant increased production (as high as 2000%), lower costs (as much as 90%), and a higher quality product for many of America's leading manufacturers. It's an amazing story — with facts and figures released by the companies themselves — and results that speak for themselves. See how these manufacturers' experiences may parallel your own . . . how RF Heating may help achieve production efficiency in *your* plant.

Send for this free booklet today — ask for B-4782. Write Westinghouse Electric Corporation, Department P-35, 2519 Wilkens Avenue, Baltimore 3, Maryland.

YOU CAN BE SURE...IF IT'S
Westinghouse

INDUCTION HEATING

J-02235



CHECK the Versatility

of the BRISTOL DYNAMASTER

Electronic temperature recorders and controllers

Dynamasters can be used with "sensing elements" like these:

Resistance thermometers, strain gauges, conductivity cells, thermocouple or radiation pyrometers, tachometer magnetos, pH amplifiers, gas analyzers, X-ray and radiation thickness gauges, photoelectric cells, spectrometers, gas detectors, titrometers, and others

To measure, record and control quantities like these:

Temperature, pressure, volts, amperes, watts, thickness, liquid, flow, liquid level, load, weight, strain, torque, position, conductivity, ionization, rpm, illumination, density, and many others

BRISTOL

The dependable Guidepost of Industry

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

..and Double Check THESE FEATURES:

All types of electric and air-operated controllers offered

Continuous-balancing electronic circuit responds instantly to minute changes

Simple design assures trouble-free operation

Little or no maintenance

Circular or strip-chart models, single or multiple recorders

Electronic component uses vacuum tubes available at any radio supply house

Full-scale pen travel in 2/3, 3, or 7 seconds

Wide variety of chart speeds

Components interchangeable on all Dynamaster models, easily serviced or replaced

Exceptionally unaffected by stray currents (1000 to 1 discrimination)

Available in bridges or potentiometers

Practically immune to shock or vibration

AND THAT'S NOT ALL! *For more details, use the coupon to send for Catalog No. P1245.*

COMPANIES LIKE THESE are using Dynamasters

North American Cyanamid Limited
Jones & Laughlin Steel Corporation
Raybestos-Manhattan, Inc. Manhattan Rubber Division
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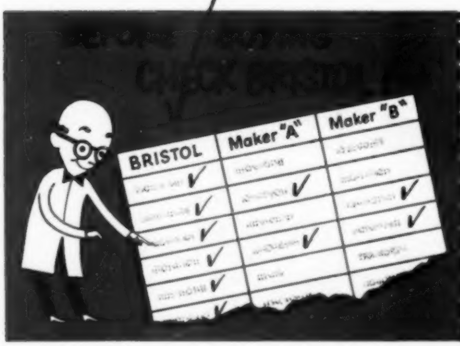
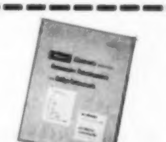


THE BRISTOL COMPANY
106 Bristol Road
Waterbury 20, Conn.



Please send catalog giving details of Dynamaster performance to:

NAME ________________ TITLE ________________

COMPANY ________________

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CITY ________________ ZONE ______ STATE ________

The Superior Tube That Speeds Up The Race

Furnishing tubing that speeds a customer's production processes is a Superior specialty.

A case in point is illustrated above. The customer, New Hampshire Ball Bearings, Inc., manufactures high-speed, precision ball bearings. They formerly machined the races for certain of their smaller sized bearings from solid stock. This represented a considerable material loss . . . and a substantial time loss in the manufacturing process.

Prime requirements for the races were concentricity within 10% of the race wall thickness, dimensional tolerances under .002" and hardness. After consultation with us the customer began to fabricate these races from 52100 Alloy Steel tubing. Time, material and money were saved and the product improved.

Such savings are almost a commonplace with Superior customers. Because of our long experience in standard production of what is generally regarded as specialty tubing, we can frequently supply a quick and easy solution to the most difficult problems . . . and generally do so without charging "premium" or special handling prices.

If you have a need for fine small tubing in any analyses . . . almost any shape . . . and of a superior quality . . . it will pay you to check with us. We may be able to fill your needs from stocks of our selected distributors in key cities. Write Superior Tube Company, 2038 Germantown Ave., Norristown, Penna.

BE SURE ABOUT TUBING—SPECIFY

Superior

THE BIG NAME IN SMALL TUBING

All analyses .010" to 5/8" O.D.
Certain analyses (.035" max. wall) up to 1 5/8" O.D.

ROUND AND SHAPED TUBING

Available in:

Carbon Steels:
A.I.S.I.—C-1008, MT-1010, MT-1015, C-1118, MT-1020, C-1025, C-1035, E-1095

Alloy Steels:
A.I.S.I.—4130, 4132, 4140, 4150, 8630, E-52100

Stainless Steels:
A.I.S.I.—303, 304, 305, 309, 310, 316, 317 321, 347, 403, 410, 420, 430, 446, T-5

Nickel Alloys:
Nickel, "D Nickel"*, "L Nickel"*, "Monel"*, "K Monel"*, "Inconel"*, 30% Cupro Nickel.

Beryllium Copper

West Coast: Pacific Tube Company, 5710 Smithway St., Los Angeles 22, Calif. UNderhill 0-1331.

*Reg. U. S. Trademark International Nickel Company

zip-zip . . .
. . . like
in LINDBERG
Well, maybe not that fast . . . but it'll seem that fast if you've ever had to struggle around with the old type heavy radiant tubes. These new gas-fired, vertical tubes weigh only 29 pounds . . . almost as light as a razor blade by comparison.
All you do is turn off the gas, get on top the furnace, lift out the old tube, lower a new one in its place . . . and that's it.
How to install new radiant tube . . . There's nothing to it. Just turn off the gas, lift out the old tube, and lower the new one in its place.
The greatest advance in industrial furnace design and construction since Lindberg introduced the Cyclone forced convection tempering furnace back in 1935!

. change radiant tubes blades in your razor!

CARBONITRIDING FURNACES

Simple, isn't it? No furnace cooling necessary . . . no extended down time . . . no clumsy plugs to unbolt . . . no squirming around inside the furnace.

But ease of maintenance is only one of the advantages offered by this amazing Lindberg Carbonitriding Furnace. Check these important construction features:

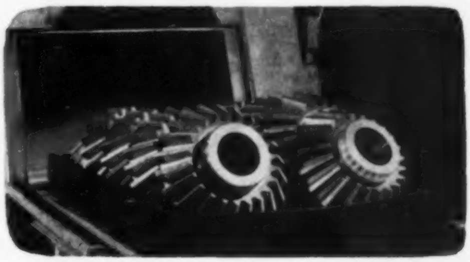
Quench tank pit unnecessary . . . Your Lindberg Carbonitriding Furnace includes a built-in pitless quench tank . . . thus you avoid costly excavation and piping. But more important, this built-in quench tank minimizes distortion . . . quenching takes place within the furnace structure, by means of a vertically operated elevator. Heated charges are never exposed to the air . . . as would be the case if work had to be transferred from the heating chamber to a separate quench tank. Uniform case depth is assured because each charge automatically remains at heat the same length of time.

Preheat and purge chamber . . . Prior to entering the furnace heating chamber, work enters area immediately above built-in quench tank. Here, work is preheated . . . this reduces drastic temperature change when work enters heating chamber. Also, the work is completely purged while it is preheating.

Many furnaces in one . . . Furnace atmosphere is provided by Lindberg "Hyen" endothermic atmosphere generator that is easily adjustable to supply different atmospheres not only for carbonitriding, but also for carburizing, carbon restoration, bright hardening or annealing and normalizing. For annealing and normalizing the heated charge cools in the same chamber used for preheating and purging.

For additional information write your nearest Lindberg office . . . or Lindberg Engineering Company, 2448 West Hubbard Street, Chicago 12, Illinois.

CARBONITRIDING . . . Specifications called for .023 to .025" case on these low carbon seamless tubes. The charge weighed 450 lbs., and required 1¾ hours.



CARBURIZING . . . 450 lbs. of these bevelled gears, SAE 1020, required three hours total time to obtain a .032" depth.

ANNEALING . . . These SAE 1045 gear blanks were annealed to 174 Brinell. Temperature was 1550° F., time 1½ hours. The charge weighed 350 lbs. Cooling was in atmosphere.

LINDBERG FURNACES

Why Brass can better serve your needs
Outstanding Performance
BRONZE GEARS, BUSHINGS AND BEARINGS POSSESS LONGEVITY UNDER CONSTANT USAGE . . .
Heavy duty machinery, which requires rugged mechanical endurance necessitates the use of materials, which must perform for extended periods of time under severe strains.
The use of bronze under these conditions is a must. Only in bronze can be found the unusual combination of plasticity, durability, strength and wear resistance required.
FREE . . . Write for your copy of the 8-page Lavingot Technical Journal — Vol. 8, No. 3 — containing an article discussing "Gates and Risers."
Specify—LAVIN NONFERROUS INGOT—Quality
Brass · Aluminum · Bronze · Zinc Base Die Casting Alloys
R. LAVIN & SONS, INC.
• Refiners of Brass, Bronze and Aluminum
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REPRESENTATIVES IN PRINCIPAL CITIES
R. LAVIN & SONS, INC.
1900
52 Years
1952
SERVING THE FOUNDRY INDUSTRY

The motor frame and polishing bowl casting are attached to a steel bracket; the unit can be easily mounted to a laboratory wall.

Wide Control, Constant Torque *with* FISHER METALLOGRAPHIC POLISHER

The new heavy duty Fisher Variable-Speed Polisher is the last word in convenience and efficiency. By setting the dial to a selected point, the precise rpm required at the moment is instantly at the command of the operator . . . and full torque is provided at all speeds.

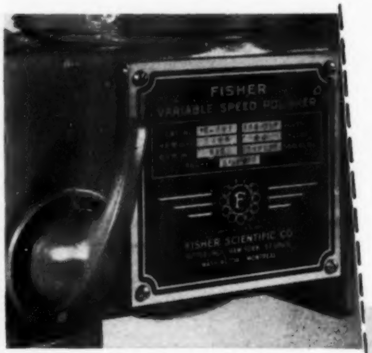
All exposed parts of the Polisher are constructed of non-corrosive materials. The bowl and splash ring are made of aluminum for durability. The bowl is sloped towards a drain plug, readily accessible from the underside of the unit. The splash ring is removable and is shaped to direct the spray from the head down into the bowl.

The nickel-silver polishing head has a 9-inch diameter. A unique locking-clutch device connects the head directly to the driving shaft, facilitating removal and attachment.

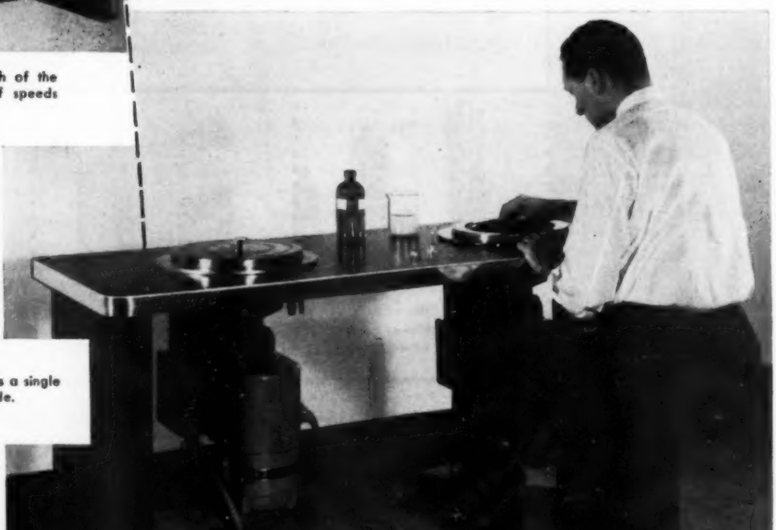
A stainless steel spring firmly holds polishing cloths of any thickness and a satin-finished nickel-plated brass cover protects the head and polishing cloth from dust when Polisher is not in use.

TWO MODELS AND MOUNTING TABLE AVAILABLE IMMEDIATELY FROM STOCK

Write for Complete Information



A selector dial (within easy reach of the operator) permits wide range of speeds without loss of torque.



New Polishing Table accommodates a single Polisher or two Polishers side by side.

FISHER SCIENTIFIC

America's Largest Manufacturer-Distributor of Laboratory Appliances and Reagent Chemicals

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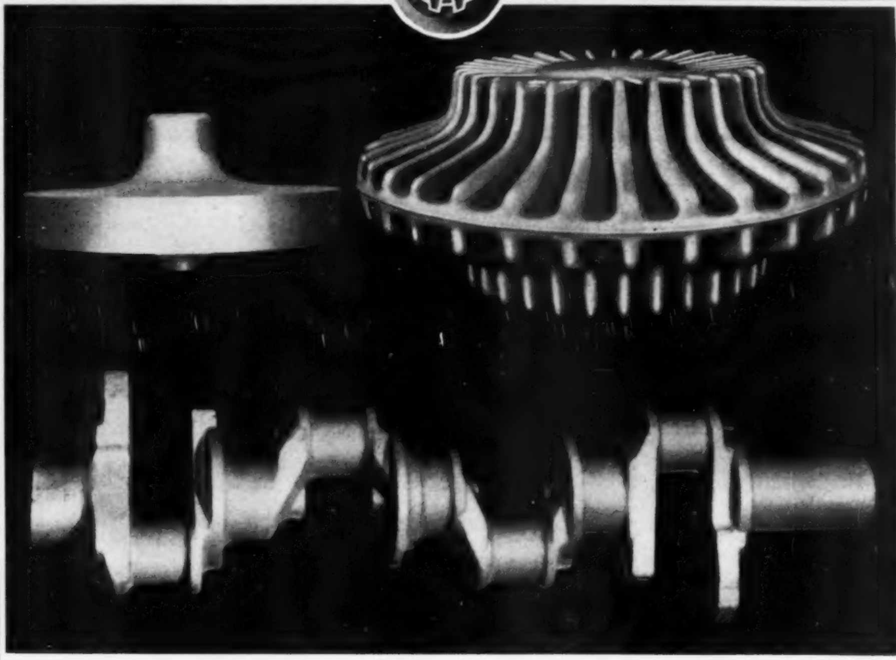


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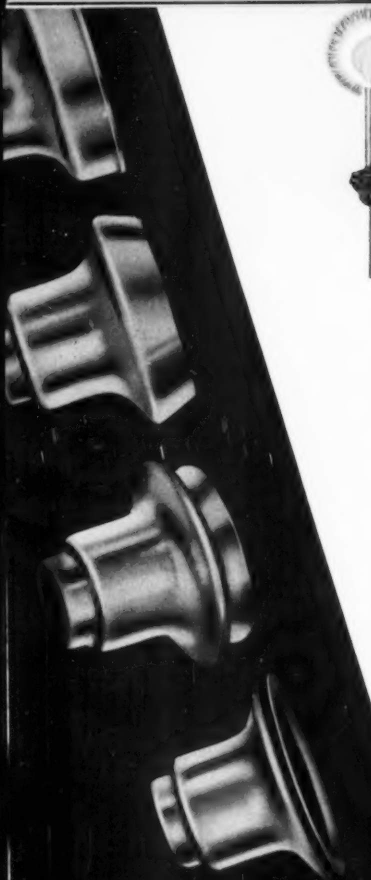
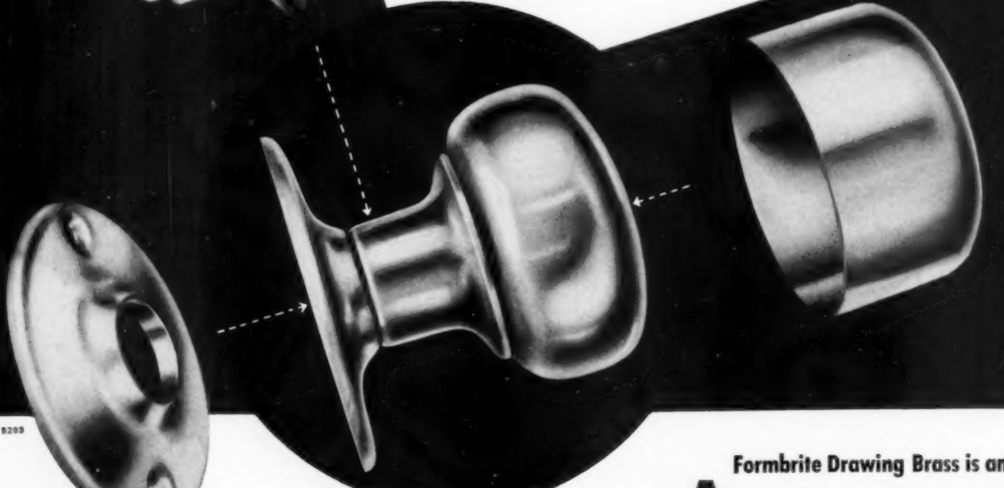




ROLOCK

FABRICATED ALLOYS

AN ASSEMBLY THAT *"Gives a Lift"* TO AN IMPORTANT HEAT TREATING JOB

Four sets of these Stacking Furnace Baskets were custom-fabricated by Rolock to fit pit-type furnaces built by Hevi Duty Electric Company. Photo at left shows bottom grid, mesh disc, lift straps and fastening keys. Photo at right shows complete assembly ready for furnace.

They are used by a nationally known manufacturer for hardening at 1850° F. Material of basket is type 330 stainless steel. Size, each basket 28" I.D. x 12¾" high. To facilitate handling in and out of the furnace the baskets are securely fastened together with alloy lift straps and keys. Note fabricated bottom grid and mesh disc. All welding is of the highest quality.

Rolock equipment is engineered to suit the specific job... for maximum strength... for as high ratio of load to weight as safety permits ... for handling convenience... and for low hour-cost through extended service life. Our engineering department likes to solve problems. Tell us about yours!

Rolock Booth No. 1810, National Metal Exposition October 20-24, 1952, Philadelphia, Pa.

Offices: PHILADELPHIA, CLEVELAND, DETROIT, HOUSTON, CHICAGO, ST. LOUIS, LOS ANGELES, MINNEAPOLIS, PITTSBURGH

ROLOCK INC. · 1222 KINGS HIGHWAY, FAIRFIELD, CONN.

**for better work
Easier Operation, Lower Cost**

DRL52

Timken wrings a 2-ton roller bearing dry

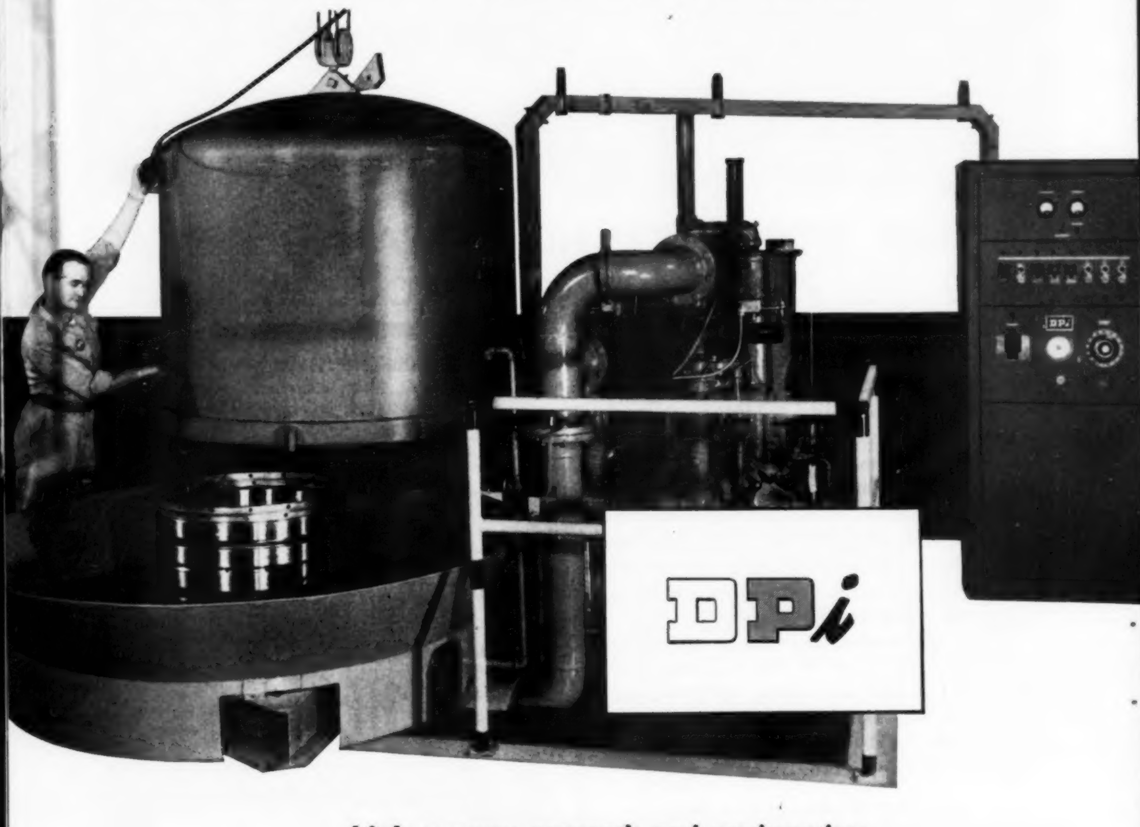
... by high vacuum

WHEN you've finished a 3-foot roller bearing and put it aside to await a call from a steel mill, it's a costly disaster to find later that the beautifully machined surface corroded despite a protective coating of petrolatum.

The Timken Roller Bearing Company has solved this problem by getting rid of the last bit of water before coating. They do it with DPi high vacuum equipment, and here's how it works:

The bearing is first washed in a hot water-soluble oil emulsion. Then it is placed in a high vacuum chamber where the pressure is quickly reduced to 9 microns Hg (about 1 millionth atmospheric pressure) and held for 20 minutes. That removes every trace of water. When covered with petrolatum, the bearing remains in perfect condition until ready for use. Using a uniquely efficient oil ejector pump, this equipment is economical to operate—is designed and built for easy, trouble-free operation.

If you suspect that high vacuum has a place in your business, our engineers are ready to discuss its applications with you, whether for dehydration, vacuum metallurgy, or any other phase of high vacuum technology. Just write ***Distillation Products Industries,*** Vacuum Equipment Department, 753 Ridge Road West, Rochester 3, N. Y. (Division of Eastman Kodak Company).

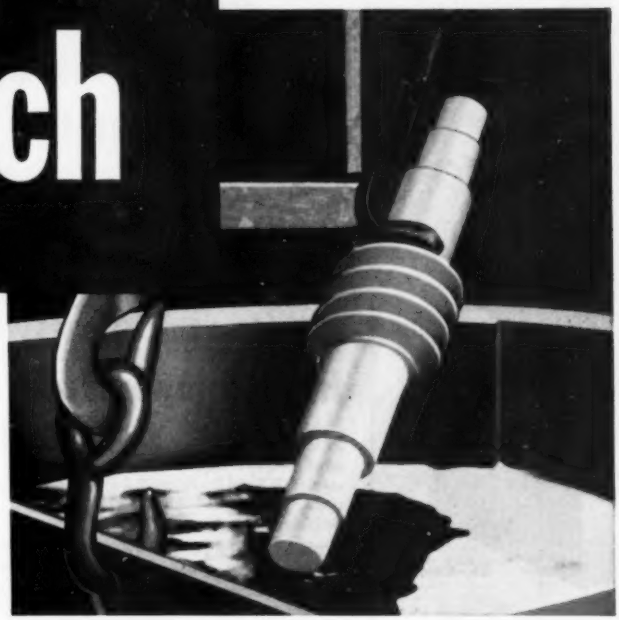


high vacuum research and engineering

Also . . . vitamins A and E . . . distilled monoglycerides . . . more than 3500 Eastman Organic Chemicals for science and industry

Houghto-Quench

this side of water!



... provides the safe, sure quenching needed for "LEAN ALLOY" steels!

Use Houghto-Quench to meet your most critical quenching needs. We developed this stable oil to give you all three of these essentials that heat treating low alloy steels demand:

1. A faster quench through the critical zone
2. Full hardness to meet high physicals safely
3. Uniform quenching of *any* steel at *any* temperature

Ask the Houghton Man to show you why it pays you to specify Houghto-Quench—particularly today. Or write to E. F. Houghton & Co., Philadelphia 33, Pa., for full information.

DO YOU HAVE OUR HANDBOOK ON QUENCHING?

Contains complete information on this important phase of heat treating. We'll gladly mail a copy, without charge, to anyone engaged in metal processing.

HOUGHTO-QUENCH ... a product of

E. F. HOUGHTON & CO.

PHILADELPHIA · CHICAGO · DETROIT · SAN FRANCISCO

Ready to give you on-the-job service ...

Ipsen 250 carbonitriding SAE 1010 Clutch Retainer Plates to C. D. of .004". Completes 225 pieces in 70 minutes.

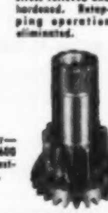
YOU CAN HANDLE JOBS LIKE THESE PROFITABLY IN THE *Ipsen*

Plier Segment—C1060 Clean hardened. Finish Grind eliminated.

Gear — C1020 — carbonitrided. Cleaning before plating eliminated.

Valve — C1020 welded to C1045—stress relieved and hardened. Retapping operation eliminated.

Release Lever—carbonitrided 600 per heat. Blasting eliminated.



Heavy Bull Gear Pinions SAE 8620 — carburized 39 per heat.

4 Important Production Advantages

with New *Ipsen* HEAT TREATING UNIT

Designed for carbonitriding, carburizing, hardening, brazing, and martempering, new Ipsen Automatic Production-Type Heat Treating Units offer outstanding production and metallurgical advantages in processing a wide variety of workpieces. The features outlined below are essentially the reasons why more than 95 plants in the past two years have selected, and are today using, Ipsen Equipment to speed heat-treating operations and cut costs:

1 AUTOMATIC OPERATION—from heat through quench (or cooling), reduces work handling, eliminates guess work, assures uniform results on a production basis.

2 BRIGHT, CLEAN, SCALE-FREE WORK—with sealed atmosphere control. Eliminates cleaning and processing operations prior to and following heat-treatment, effects substantial savings in production costs.

3 CRACKING AND DISTORTION REDUCED—by controlled quenching with two-speed oil circulation and automatic temperature regulation.

4 FAST, EFFICIENT PROCESSING—versatile and easy to handle variety of work, no idle time for change-overs, no danger of burring or marring, quick burn-off. Saves time, increases output.

THE AUTOMATIC Ipsen

Write **TODAY FOR MORE FACTS** . . . Ask for free bulletins and find out how Ipsen Heat-Treating Units and methods can be applied to your work. If you wish, samples or production lots of your work will be run, proper procedures established, and results predetermined without obligation.

IPSEN INDUSTRIES, INC. 723 South Main Street, Rockford, Illinois
Production Units for CARBONITRIDING · CARBURIZING · HARDENING · BRAZING · MARTEMPERING

6 reasons why

NIALK® TRICHLORethylene

is your best buy for Fast, Low-Cost metal degreasing

1. QUICK ACTING . . . Cleans and dries in record time. And after rapid degreasing of surfaces, metal is warm, dry and ready for further processing.

2. SAVES MONEY ON POWER . . . Low boiling range means quick vaporization. Can be heated by gas, steam, or electricity. Produces a concentrated vapor at only 188°F.

3. SAVES MONEY ON SOLVENT . . . High vapor density means proper vapor level will be maintained in the degreasing machine. Result: more efficient cleaning with low solvent loss.

4. NON-FLAMMABLE . . . At room temperature there's no worry about fire when you take the ordinary precautions required in the handling of any chlorinated hydrocarbon.

5. STABLE . . . NIALK TRICHLORethylene can be used for all-purpose degreasing.

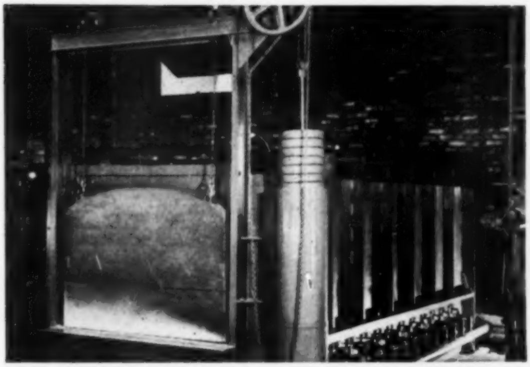
6. ECONOMICAL . . . Completely re-usable after distillation.

Make sure your metal parts are 100% grease-free. NIALK TRICHLORethylene leaves them clean, warm, dry, ready for immediate electroplating, painting, enameling, lacquering, rustproofing, heat treating, pickling, inspection or assembling.

NIAGARA ALKALI COMPANY

60 East 42nd Street, New York 17, N. Y.

NIALK Liquid Chlorine • NIALK Caustic Potash • NIALK Carbonate of Potash • NIALK Paradichlorobenzene
NIALK Caustic Soda • NIALK TRICHLORethylene • NIAGATHAL® (Tetrachloro Phthalic Anhydride)

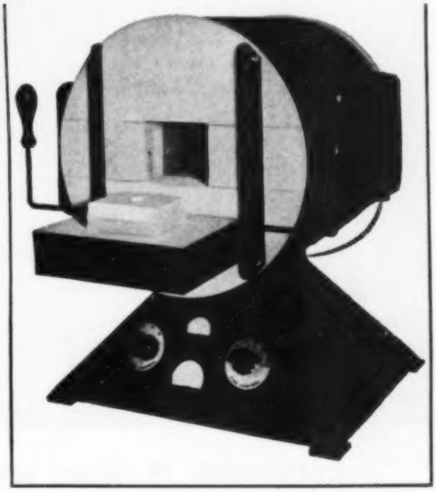


BARKLING FUEL ENGINEERING CO.

The hearth of this furnace is made of CARBOFRAX tile. This is a gas fired, heat treating furnace used for general heat treat work. Operating temperatures range from 1500 F to 1900 F. In this application, the hot strength and unequaled abrasion resistance of CARBOFRAX refractories plus their high thermal conductivity, are the properties most needed.

HEVI DUTY ELECTRIC CO.

A CARBOFRAX silicon carbide muffle is used in this electrically heated, laboratory furnace. Temperatures range from 2000 to 2600 F. The furnace is used for heating metals, firing ceramics, hardening tool steels, making ash determinations, and for general laboratory work. If desired, the muffle can be sealed and an artificial atmosphere used. Being made of CARBOFRAX refractory, the muffle conducts heat rapidly, resists cracking and abrasion, and has a long life.



Someplace

in almost every heat treating furnace you'll find Super Refractories by

CARBORUNDUM

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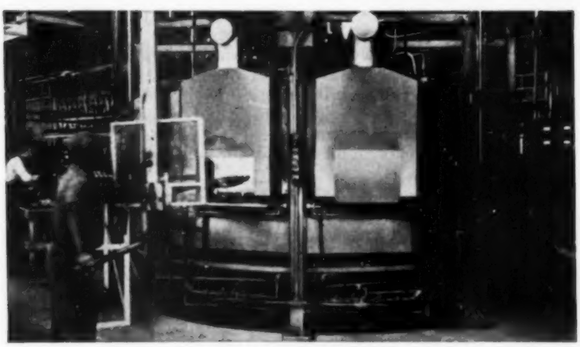

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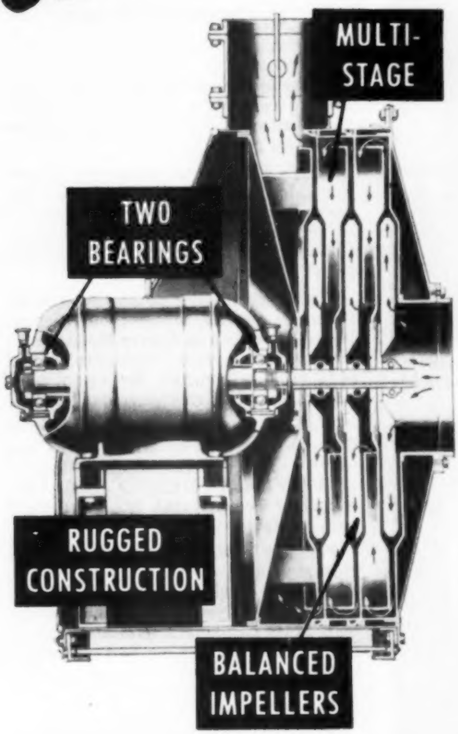

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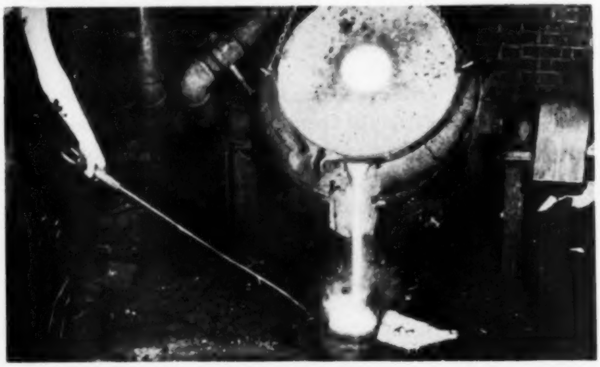

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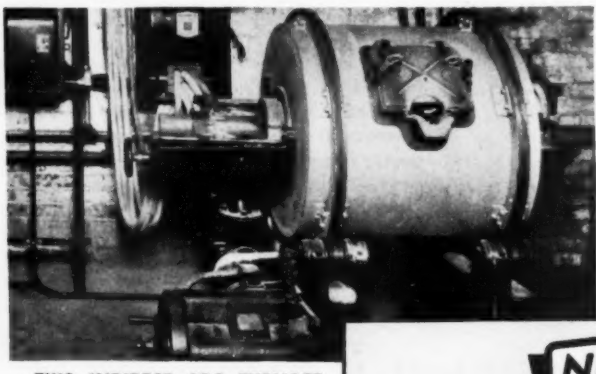

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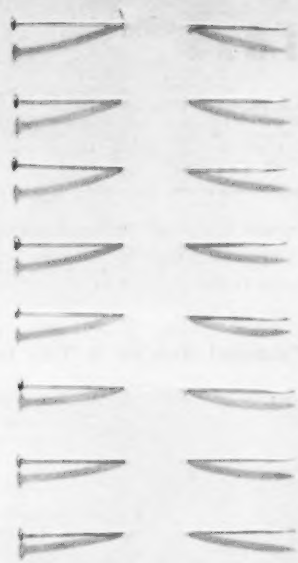
Metal Progress

Vol. 62, No. 3 · September, 1952

Technical Articles in This Issue

Departments

Abstracts of Important Articles



By A. L. Boegehold, Asst. to General Manager, Research Laboratories Div., General Motors Corp., Detroit

Selection of Steel for Automobile Parts*

THE SUBJECT "Selection of Steel for Automobile Parts" has been discussed four times in the past 15 years by this author but each time with a somewhat different approach, depending on the state of our knowledge of the subject.

Now that all constructional alloy steels used for automotive parts have been classified in terms of hardenability bands, we frequently hear the statement that two steels of the same or equivalent hardenability can be used interchangeably in an automotive part with equal performance in service. This statement is true only when the steel in question has considerably more hardenability and resistance to fatigue than is actually needed for the part. But if the steel used for that part has just enough hardenability to provide the necessary physical properties — then I would hesitate to guarantee that a steel of equal hardenability, used for the same part, would give satisfactory service.

Laboratory tests on steels determine tensile strength, yield strength and ductility, hardenability and hardness; but we can't use those physical properties to determine how the steel is going to perform in service. We get some idea of the character of the steel, but that is all. To determine what the steel will do in a component part of an automobile in service, we have to make a simulated service test, or a service test of a completed car at the proving ground. The reason for this is that laboratory tests on small standardized specimens of simple shape do not represent the conditions that exist in the component. Furthermore, due to processing operations and processing treatments, there is a pattern of residual stress in the component which is not present in laboratory test specimens. There is also a pattern of stress concentration due to externally applied loads that is peculiar to the part in question.

So possibly the question arises, "Of what use is hardenability if you can't use it for selecting steels for service?" It helps us a great deal in picking out the steels to be used in a program of tests. Only the steels that will provide the component with the required hardness pattern can be used for service tests. The result of service tests will finally decide what steel is going to be used for manufacturing the part — if there is no overpowering objection due to cost of raw material or its fabrication.

Another thing we have to remember is that steels of different hardenabilities may not give different results in service in the same ratio as the difference in hardenability. For example, a steel of higher hardenability does not necessarily mean that it is going to perform better in service than a steel of low hardenability. The steel of lower hardenability may require more drastic quenching to harden satisfactorily, but the hardness level will not be as high as obtained in a higher hardenability steel; therefore, lower tempering temperatures will be used to bring the part to the hardness level needed in service. Those different hardness patterns, as-quenched, and different tempering temperatures will result in different stress patterns in the tempered part, so their performance might be quite different. As a matter of fact, the lower hardenability steel might perform *better* than the higher hardenability steel at equal surface hardness, as a result of a more favorable residual stress distribution.

Hardenability Versus Endurance Strength — In a discussion of the then new "National Emergency" steels (later standardized as the triple-alloy steels from 86xx to 98xx available both to chemical specification and to hardenability limits), Harry B. Knowlton presented two graphs that bear directly and clearly on the points I want to make. He and his associates, F. Sailer and E. H. Snyder, investigated 11 alloy steels made into $2\frac{3}{4}$-in. axle shafts, all heat treated to obtain approximately the same tempered hardness at the surface. Performance was then com-

*This article is the second and concluding portion of a talk presented to the Rochester Chapter, American Society for Metals, in March 1951, to the General Motors Metallurgical Committee in February 1951, and to a meeting of the department heads of the General Motors Research Laboratories that same month. The first installment appeared in the August issue of *Metal Progress*.

Performance Tests Show Variation

pared by subjecting the shafts to torsional fatigue. Figures 8 and 9, reproduced from the original article in *Metal Progress* for December 1943, contain the pertinent data.

It will be noted in Fig. 8, showing the hardness traverses on centerline across a section of the shaft, that all of the steels have a hardness between about Rockwell C-34 and C-40 at the surface, which is the commercial limit for the shaft.

Now observe the hardness curve of 1046, a plain carbon steel, and compare it with the curve for 8744 steel, a low-alloy Ni-Cr-Mo steel. There is quite a difference at the center, but at the surface the hardness is quite similar. In this diameter of section the 1046 probably had to be drastically quenched with water to obtain enough hardness to end up with the hardness pattern shown in Fig. 8.

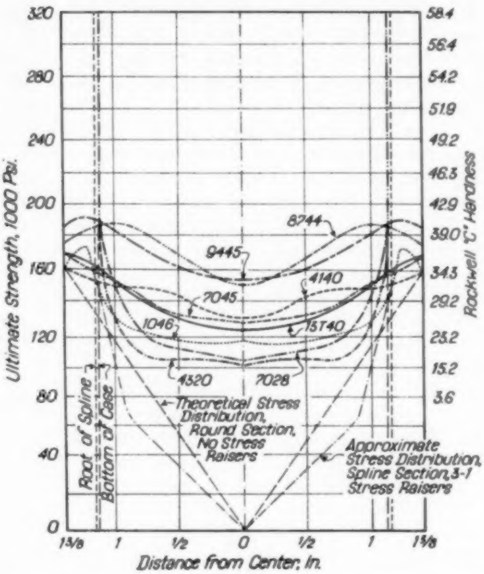
The 8744 steel was oil quenched and drawn at a higher temperature than the 1046. From Fig. 9, showing fatigue tests on full-sized axles, it is seen that 1046 was comparable with the 8744, both being in the zone of "medium fatigue strength". Anything that comes in this intermediate zone is considered more or less equivalent because, if a large number of shafts of the steels with the same heat treatment were tested to obtain more points, the spread would probably still be within this range. So we have here an example where a low-hardenability plain carbon steel performs just as well as an oil-hardening steel with higher hardenability.

Going back to Fig. 8, we can again compare steels of equal hardenability and equivalent hardness cross-section pattern by comparing 4140 with 7045. Similar treatment in quenching and similar tempering temperature would produce that hardness pattern in these two steels.

Referring again to Fig. 9, to compare the fatigue test results for these two steels, we find 4140 again in the intermediate zone, but the arrowheads representing 7045 fall in the low zone of fatigue strength. Despite the large scatter in these results which prevents one from drawing an average line, a number of the tests on 7045 fall well below the curve drawn for 4140. This is an example in which steels of approximately equal hardenability, hardened and tempered to the same cross-sectional hardness, perform quite differently in a simulated service test.

A third comparison can be made be-

Fig. 8 — Cross-Sectional Hardness (and Strength) of Axles After Heat Treating, Compared With Theoretical Distribution of Stress



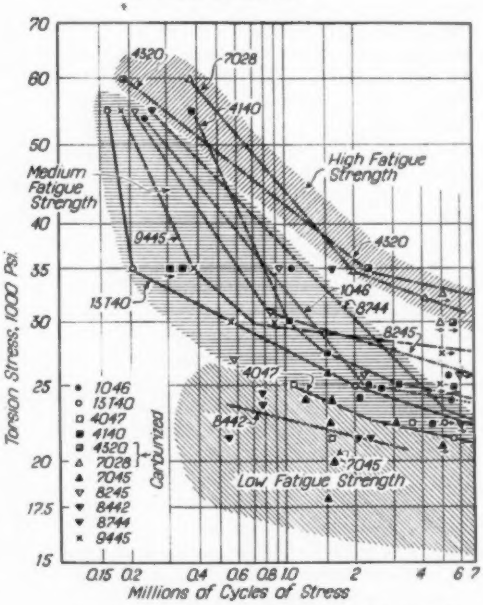


Fig. 9 — Torsion Fatigue Tests on 2¾-In. O.D. Splined Axles, Made of Nine Medium Carbon Steels and Two Carburized Steels. Steels 7028 and 7045 contain 1% manganese and 0.28 and 0.41% molybdenum respectively

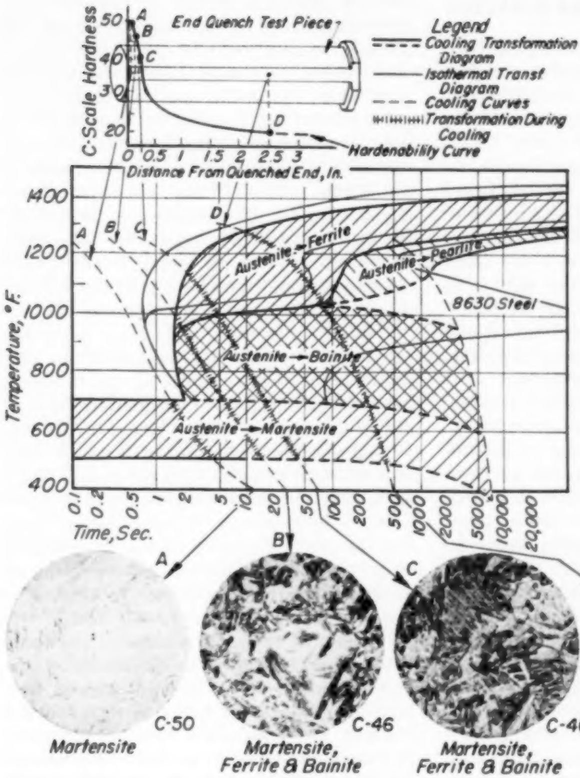


Fig. 10 — Schematic Relationship of the End-Quench Hardenability Test to a Cooling Transformation Diagram Derived From Isothermal Data for a Typical Low-Alloy Steel (8630)

tween 4140 (Cr-Mo steel) and 9445, a triple-alloy steel having 1.00 to 1.30% manganese. The latter is a high hardenability steel which probably required the highest tempering temperature of any of the steels in this group to bring the hardness down within the range of this test.

Apparently the equivalent strength of 4140 (160,000 psi.) is considerably less than the strength of the 9445 (about 185,000), as indicated in Fig. 8. On the basis of laboratory tensile tests then, you would say that the 9445 should be more fatigue resistant than the 4140 steel. Figure 9 tells us that resistance to fatigue of these two is practically equivalent when tested as full-sized, heat treated axles, judged by the fact that all the test results except two fall in the zone of medium fatigue strength.

Origin of Stress Pattern

These three comparisons all constitute evidence that performance in service is not a direct function of hardenability but is determined by several additional factors.

In order to obtain a more complete conception of the differences between steels in terms of hardenability and internal stress pattern, we should take into consideration all of their transformation characteristics. To discuss this, use will be made of Fig. 10, which shows in light line the time-temperature-transformation curve of 8630 steel, commonly called an "S-curve", or a "TTT-curve". The S-curve, as is well known, is determined by measuring the time for transformation while temperature is held constant. But in ordinary heat treating, as is equally well known, we don't hold the parts at constant temperatures for transformation except in very special treatments — we cool in a quenching medium and so we get transformation at a constantly decreasing temperature. Transformation diagrams for various cooling rates can be derived approximately from the S-curves as is shown in full lines in Fig. 10, or from the end-quenched hardenability specimen.*

Referring now to Fig. 10, four points

*Editor's Footnote — This method of deriving a transformation curve during continuous cooling was originated by C. A. Liedholm and described in *Metal Progress* for January 1944. It should also be stated that the standard end-quench test for hardenability was first proposed by W. E. Jominy and A. L. Boegehold in 1937.

Correlation of Hardenability and S-Curves

A, B, C and D on the hardenability bar are chosen, representing several different rates of cooling: A at the surface of the quenched part, B and C somewhat under the surface, and D at the center of a sizable piece.

The corresponding cooling curves A, B, C, and D are shown imposed on the transformation chart. Now the path of the temperature with time, through the various transformation zones, determines the final hardness and the final structure shown at the bottom. At the top of Fig. 10 the hardness is represented on a curve showing hardness as a function of distance from the quenched end of the hardenability bar.

We can consider that those four cooling curves represent the different modes of cooling at different points in a round or shaped bar that is totally immersed in the quenching medium, and will reveal what is taking place at varying distances below the surface. The zone in the transformation diagram through which the cooling curve is passing determines the nature of the transformation. When transformation of austenite begins, there is a volume increase; contraction is resumed with falling temperature after that initial volume increase.

At some stage of cooling, when the surface has gone through the transformation, has expanded in volume, and has started to contract again, there is some other place in the cross section nearer the center which is beginning to transform and to expand. For example, point A at the surface starts to expand about 1½ sec. after entering the quench, point B slightly under the surface about 2 sec. after entering the quench, and point D at the center does not start to expand until it has been in the quench for 10 sec. Completion of the transformation at the surface occurs before transformation at the center begins. These opposite volume changes occurring concurrently throughout the cross section are responsible for opposing plastic movements which create the residual stress patterns having so much effect on the performance of components.

Some other steel could have much the same hardenability (as measured on this hardenability test specimen by the H-curve) but could also have transformation zones of different shape and size. The top line of Fig. 10 that denotes the beginning of transformation could be at a lower temperature and the areas wherein certain transformation products are formed could be of different sizes, and the product could be different in microstructure and still have the same hardness as obtained by the end-quench cooling curve as in the first example for 8630 steel.

Thus, in some other steel of the same H-band hardenability, the quantities of several kinds of microstructural phases that form to produce the same hardness in the finished hardened part can be different; therefore, the type of structure, the volume associated with its formation, and the time, location, and volume change relationship can be quite different, steel to steel, even though both have substantially the same hardenability curve in the end-quench test. Consequently, the residual stress pattern can differ in heat treated parts made therefrom.

One thing is sure and that is that the situation is very complicated — so much so, in fact, that it is manifestly impossible to study those transformations and try to predict how a piece of steel is going to perform in service.

From what has been written above, and from the discussion in the last issue of the relationship between the steel, its design, shape of part, heat treatment and the endur-

Fig. 11 — Gears Were Among the First Parts Made of Alloy Steels in Automobiles. Today they still are the type of parts which require careful selection, processing and treatment

ance of the part in dynamic service, we can see that the final selection of the material for a certain component is not a simple procedure. The design engineer is always interested in short-circuiting everything complicated if possible. Who isn't? Very frequently requests come from engineers asking the metallurgist to prepare a chart or a couple of charts that will contain all the essential information for selecting steels for use in components. The engineer would like to have such a chart to help him make his own selection when drawing up the details of the component parts.

CONSTRUCTING A DESIGN CHART

Such a table might be one in which the first column would give the desired tensile strength after quenching and tempering, and the second, third, fourth . . . columns would be headed ½ in., 1 in., 1½ in., 2 in., and so on. In each of these columns, opposite each strength level, would be the designation of the standard steel which would develop that strength in the indicated size after "normal" heat treatment.

While I am not prepared to state definitely that such a chart would be of more harm in the hands of an unwary user than it would be of help to a careful engineer, the text and illustrations in these two articles will give some idea of the pitfalls. We must always appraise the state of the metallurgical art — not only as practiced by the steelmaker, but by the metals engineer in the shops fabricating machinery.

For example, it was mentioned that automobile ring gears made of a rather expensive, high-alloy steel were installed in one of our lowest priced automobiles up to 10 or 12 years ago. One of its advantages was that, when quenched, it had a considerable amount of retained austenite in its structure, a metallographic phase that is ductile enough so the gear teeth could conform somewhat and give a good bearing against other teeth. Note that a considerably higher degree of accuracy in the gear shaper — a purely machine shop operation — was necessary before a satisfactory change could be made to a lower alloy, less expensive steel that could be heat treated to the same hardness pattern but would have much less retained austenite.

It is an old saying that alloy in steel is very valuable to cover up sloppy heat treatment. This is another way of saying that economy in alloys (especially in time of emergency) must go hand in hand with advanced engineering in all phases of parts design and manufacture.

This brings us back to an observation that the chart which designers are calling for would be one thing for the most advanced practitioners and another thing for plants which are still operating in the World War I era.

A specific instance, somewhat less complex in nature than a carburized ring gear, is the gas engine crankshaft. It is well known that one prominent American manufacturer has had much success with a casting for this part. On the other extreme, I have before me a drawing for a forged crankshaft for a military vehicle specifying $2\frac{3}{16}$ in. diameter as forged, C-42 hardness at half radius as quenched, and C-20 to 26 after tempering. To meet this hardness, as quenched, a steel with considerable alloy would be needed — not only costly but difficult to machine.

The interesting thing here is that similar crankshafts, C-20 to 26 hard as tempered, have been made of plain carbon 1045 steel for at least 30 years, and have operated *very* successfully.

The practical question here relates to the proposed design chart. In the appropriate line under 2½ in. diameter, would you put cast semisteel, 3140, or 1045?

A much more feasible plan is one where the component is named and various sizes listed. Then a figure for minimum hardness at specified depth — say center or half radius — could be listed. This figure would be selected in the light of service experience acquired by various manufacturers. Then it would be the duty of the metallurgist, thoroughly familiar with the fundamentals involved, to select a steel which could be bought readily, would meet the hardness specification after quenching in the available equipment, and would be most economical in alloy consumption and machining and related costs.

With the passage of time, revisions would undoubtedly be made in such a "Performance Requirements Chart" to bring it into line with actual practice. Such a chart would then be of great service to designers, engineers and metallurgists.

Reported by Bruce W. Gonser, Assistant Director, Battelle Memorial Institute, Columbus, Ohio
(Chairman, A.S.T.M. Committee B-2 on Nonferrous Metals)

The American Society for Testing Materials Looks at the Metal Tin

THE MODERN tendency to buy and sell metals according to analysis rather than by brand name has not yet reached as far as commerce in the metal tin. In fact, it is the only common metal *not* covered in this country by specifications. True, tin purchased by the Government for stockpiling is analyzed and classified, but that doesn't apply to normal commercial purchases. Much of the delay in writing specifications for tin can be laid to our almost-total dependence upon foreign tin, and to the general feeling that the consumer in recent years was lucky to get tin of any analysis.

Now that there is a possibility of a free market for tin, the advocates of a systematic classification according to quality have been greatly strengthened, particularly since about half the tin now used in this country is produced (smelted) here. So many requests for tin specifications have been received by the American Society for Testing Materials that Committee B-2 of that organization was asked to look into the possibilities of a specification which would be mutually acceptable to producers and consumers. As a result, a tentative classification that could be used as a basis for specifications has been drawn; however, it may be some time before it is revised, accepted, and ready for publication.

An associated activity of Committee B-2 has been the organization of a short symposium on tin that was given June 23 in New York during the A.S.T.M.'s 50th anniversary meeting. Some half-dozen papers were presented, and a panel discussion on methods of analysis was held. The general purpose of this meeting was to overcome some widespread misunderstandings concerning the problems of tin producers, and the analytical difficulties which supposedly interfere with agreement between laboratories of buyers and sellers of high-purity metal. Finally it was hoped that information could be presented on some applications of tin and the actual effects of minor impurities.

F. S. Miller, vice-president of the Pacific Tin Co., opened the meeting with a useful and interesting discussion on tin deposits, resources, and problems in production. In 1951, 60% of the known world production came from Southeast Asia — Malaya, Indonesia, Thailand, Burma and Indo-China. About 20% came from Bolivia, 13% from Africa, and the remaining 7% from China, Australia, Portugal and 23 other countries. Surprising to many of those present were statistics showing that world production of tin in each of the past four years has been substantially in excess of consumption. A surplus of some 107,000 long tons has accumulated in that time, and has been used largely to build reserve stocks in the United States. Scarcity of tin in this country has resulted, therefore, from the policy of building an even larger reserve or stockpile, rather than from any negligence of the producers in increasing production. The present rate of overproduction of tin, amounting to 25,000 long tons annually (more than 15% of the total in 1951), is a source of concern to producers, since absorption of this excess in the U. S. stockpile will probably take place over a period of a relatively few years.

Mining in Southeastern Asia has been largely by dredging (57%), with gravel pumping and "hydraulicking" accounting for 35%; only 5% of the tin comes from underground and open-cut mines. The trend in grade of the gravels worked in Malaya and Nigeria, and the ore in Bolivia, is downward. (See Table I.) It is expected that this decline will continue, and it may be necessary and practicable to dredge ground carrying only 0.2 lb. of tin per cu.yd. Obviously, this means higher costs and will necessitate

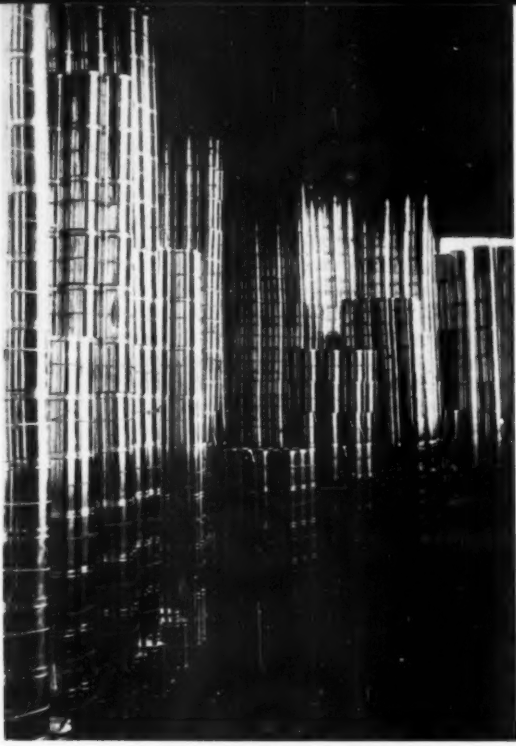


Fig. 1 — Tin Cans Gleam Like This Before They Reach the Grocer's Shelf. (Photo by W. M. Kimball)

greater operating efficiency, such as by deeper digging in low-grade deposits. The marked decline in grade of ore in Bolivia does not mean that the tin mines are being exhausted, but that the higher-grade veins are being followed into the huge reserves of lower-grade ores, which will have to be worked whenever it becomes economically sound. If experience in copper mining is any criterion, engineering means are available for the cheap and expeditious handling of these low-grade ores.

One of the big future problems in Malaya is the lack of prospecting for new tin-bearing areas. It is difficult enough to mine tin when constantly threatened by Communist guerrilla attacks, and each tin mine has become an armed camp; outside prospecting is just about impossible. This has handicapped planning for future development, but has encouraged reworking of previously mined ground. Reworking does not merely mean that poor work was done previously, but the nature of some of the workings is such that weathering has freed additional cassiterite. (To some superstitious Chinese workers this constitutes further evidence that tin is alive and will grow if left undisturbed.*)

In Indonesia, new large dredges have increased the output to above the prewar level. Some excellent tin recoveries have been reported by dredging submerged valleys offshore. This going-to-sea in dredging operations may open sizable new tin resources, since there is reason to believe that these shallow valleys frequently extend many miles offshore. Offshore dredging along the Thailand coast likewise may be extended in the foreseeable future.

Known reserves of tin placers and ores, plus additional reserves which can doubtless be developed, indicate maintenance of tin production at present levels for as far ahead as we can see — say 25 years. Geologically, there is no shortage of tin in the ground, and the engineering capacity to produce it exists. The complications come from cost of production and particularly from political considerations. The threat of Communist interference with tin production in Southeastern Asia is by no means remote. Neither is nationalization of mines in Bolivia — an event which would likely result in lower production efficiency.

Table I — Trend in Grade of Tin Ores or Tin Gravels Mined

Source	1939-1940	1948	1950-1951
Malaya, lb. tin per cu.yd.	0.45	0.44	0.36
Nigeria, lb. tin per cu.yd.	1.62	0.73	0.50
Bolivia, % tin in ore			
Patino, Catavi Mine	2.31	1.60	1.20
Hochschild Group*	2.88†	1.91	1.72
Aramayo, Chorolgue Mine	4.55	3.30	1.40

*Average from two mines, unweighted. †1941.

*Editor's Footnote — In Herbert Hoover's fascinating "Memoirs" (the first volume entitled "Years of Adventure") he describes some journeys to inspect some gold areas mined for centuries by the Chinese. "Spread over the valley were hundreds of mat-shaped stone mills, each propelled by an ever-circling pony or mule. These stone mills were the same as those that humanity has used to grind its grain since the days of Ancient Egypt. Each ground up a few score pounds of hard quartz a day, from which the free gold was washed out over a blanket. The tailings were zealously saved, for the Chinese believed that gold grew in them. Indeed it did, for with oxidation more gold was freed, and they were worked over and over."

Tin-Plate in the Container Industry

The tin-can industry is by far the largest consumer of tin, according to Richard R. Hartwell of the technical service division, American Can Co. About half of the primary tin used in the United States goes into the manufacture of tin-plate, and this is used largely for can manufacture. Production of electrolytic tin-plate since 1940 has drastically reduced the amount of tin consumed. It is now only about 0.75 lb. per base box (that is, a layer 0.000045 in. thick) compared to 1.5 lb. in 1935 to 1940. The tin used in solder for side seams has been even more drastically reduced, from 37% to less than 5% tin. Use of differentially coated tin-plate (electrolytic tin-plate with a relatively heavy coating for the inside of the container and a light coating for the outside) promises to extend this trend of conservation into the field of corrosive food packs, still occupied by hot dipped tin-plate. However, the corrosion shelf-life of food cans is controlled by many factors other than thickness of the coating. Hot dipped tin-plate has given consistently good protection, whereas individual lots of electrolytic plate of the same tin thickness may vary widely in shelf-life. The biggest factors seem to be the condition of the steel surface at time of plating and the proper adjustment of conditions in the plating line. These factors, never closely defined, are now being brought under control commercially; hence, further displacement of hot dipped tin-plate by differentially coated electrolytic tin-plate is to be expected. The importance of the steel surface has been shown by the fact that some lots of electrolytic tin-plate have given better shelf-life than hot dipped plate with a coating two and a half times as thick.

Another trend is toward the use of combination containers — those with enameled, lightly electrocoated ends, and hot dipped bodies. Side-seam striping of enameled cans, to give added protection to the seam when used with strongly corrosive products, is another means for getting the most out of a thinner tin coating. Use of materials not now produced for the container industry is also visualized. The long-term trend of economizing in tin by the container industry is far from finished, and it appears reasonable to expect that before long the average coating weight for tin-mill products will be closer to a third the prewar average than the present half.

Grade A tin is conventionally used for plate, and there is no reason to suspect that anything is to be gained from the corrosion viewpoint by going to higher purity. Moreover, the electrolytic process itself gives a more highly refined and therefore purer coating than does the hot dip process.

COATINGS OF TIN ALLOYS

Other types of tin coatings were described in a paper by F. A. Lowenheim of Metal and Thermit Corp. This field offers considerable promise for expansion, particularly in the electrodeposition of tin alloys. Plating of tin-lead or solder from fluoborate electrolytes has some useful applications. A coating of 85% copper and 15% tin is a useful stop-off when nitriding steel, and a similar composition with about 10% tin has been used in Great Britain and elsewhere as an undercoat in chromium plating. Speculum or white bronze (45% tin, 55% copper) provides a bright, decorative coating that requires no buffing and is superior to silver in tarnish resistance. Tin-zinc is replacing some cadmium plate and is easily soldered. Tin-cadmium is being used by the Navy for severe corrosive serv-

Fig. 2 — High Speed Soldering of Black Iron Plate Made Possible Wartime Production of Coffee Cans Despite the Tin Shortage. The seam needs only a strip of tin for soldering. Cans are shown passing through the soldering station. (Photograph by American Can Co.)

ice. A recent development by the Tin Research Institute is a bright coating of 65% tin and 35% nickel that has outstanding resistance to atmospheric corrosion; if tin can be made available, widespread commercial applications are very likely to follow.

Tin has been co-deposited with gold for color, and with silver to retard tarnishing. Possibly one of the most interesting applications (although minor from a tonnage standpoint) is the use of a flash coating of tin over platinum, no less, to improve the appearance of jewelry.

Electrodeposition provides a high-purity tin which is more prone to transform from the white to the gray allotropic form. Consideration has therefore been given to co-depositing purposely a little bismuth or antimony when any possible chance of transformation must be prevented.

Metal spraying, immersion in an aqueous bath, decomposition of a volatilized tin compound, and variations in electrodeposition provide wide ranges for tin and tin alloy coatings to fit almost any condition.

AUTOMOBILE BODY CONSTRUCTION

Homer C. Pratt, project engineer with the Fisher Body Division of General Motors Corp., described the problems encountered in soldering automobile bodies. For "tinning" the steel surface along joints and welded seams, a satisfactory flux consists of 74 to 95% zinc chloride, 19% (maximum) ammonium chloride, and 5% wetting agents and stabilizing compounds. This is mixed with water and solder powder to form a suspension that is readily applied with a paint brush. The steel surface is then heated to melt the solder, and the molten solder is wiped with a cloth to give a surface suitable for filler material. Tin for the latter is from 15 to 30%, usually near the upper limit. This procedure has saved more than 50% of the weight of bar solder commonly used prior to 1946, even though the tin content of the solder (filler) has remained about the same.

Ten years ago filler solder (applied in larger quantity to fill irregularities) was composed of 20% tin, 1% antimony, remainder lead. Tin was drastically restricted for this purpose in the war years; after trying many other lead-base alloys, a composition has been adopted that consists of 2.5 to 4% tin, 4 to 5.25% antimony, 0.6% arsenic, remainder lead. Filler solder is usually supplied in small extruded bars which seem to retain a finer grain after melting than cast bars. (The reason for this is not clear.) This solder has reduced by 82% the amount of tin used in filler material.

ANALYSIS OF TIN

Production of high-purity tin is accompanied by the problem of finding dependable methods of analysis for the impurities. A paper by Marie Farnsworth and Joseph Pekola of Metal and Thermit Corp. recommended methods of analysis for each of many impurities. A big analytical advantage with tin is that it can be readily removed from impurities (except arsenic and antimony) by volatilization as the bromide. Colorimetric methods seem to be the best means for determining impurities after volatilizing the tin.

In the ensuing panel discussion of analytical methods, it was brought out that spectrographic analysis of tin has also been brought to a high state of development. Thus, comparatively simple and accurate analytical procedures, both by the spectroscope or by wet means, appear to be available. Estimates of cost compare favorably with those for chemical analysis of other common nonferrous metals.

The effect of impurities on the performance of tin was evaluated by F. J. Dunkerley of the University of Pennsylvania in a compilation of data from existing literature. While this paper is not amenable to concise summarizing, one obtained the impression that most of the impurities in tin can be tolerated in rather large amounts, depending upon the application. For example, restrictions could differ widely for solder, for bronze, and for bearing metals, and any classification of impurity tolerance certainly would have to consider the intended use. Much more precise information on the effect of impurities is needed.

A more complete account of this symposium will be published by the American Society for Testing Materials as a "Special Technical Publication". The six papers reviewed here will be printed in full, together with the information brought out in the panel discussion on Analysis of Tin. Publication of the symposium is tentatively scheduled for late fall.

By James T. Waber, Los Alamos Scientific Laboratory, Los Alamos, N. M.

A Generalized View of the Scaling Behavior of Metals

With today's emphasis on metals for elevated-temperature use in rockets, turbines, and atomic reactors, the problem of scaling is acute. An extensive amount of practical information concerning the scaling of metals has been accumulated during the past fifty years. This article presents a few reasonable generalizations which have been derived from this information, together with facts which appear to be anomalous.

Anyone who has handled corroded metals has observed that the texture and character of the scale can vary considerably. Sometimes it is porous and flaky; sometimes dense and adherent. Oxides range in thickness from a few hundred Ångstroms, which will produce interference tints on the metal, to a half-inch or more. Experience has taught that the dense, adherent scales are protective and prevent direct contact between metal and oxygen. Such scales interfere with further oxidation, and the most protective scales are those that most effectively stifle growth. In contrast, loose, porous scales permit rapid and unhindered oxidation. How scales of such variety form and grow is a matter of considerable importance.

In metal scaling research four definite scale growth equations have been accepted. They are called "growth laws" and in the order of decreasing frequency of use they are: the parabolic, the linear, the logarithmic, and the cubic.

The first is the result of diffusion control. When the scale is nonporous, contact between metal and air is maintained by diffusion — either of metal ions outward to the scale-gas interface or of oxygen ions inward to the scale-metal interface. Reactions controlled by diffusion follow a parabolic growth law* represented by the equation

$$y^2 = 2Dt \qquad (1)$$

where y is the scale thickness, t is the elapsed time, and D is the diffusion coefficient. An increase in the scale thickness decreases the diffusion rate; therefore the scaling reaction slows with increasing time.

When the oxidation or scaling rate is constant and unaffected by a decelerating diffusion process, the linear growth law is observed:

$$y = k_1 t \qquad (2)$$

where k_1 is the linear rate constant. If corrosion follows this trend, it is generally the basis for deciding that the oxide is porous and that oxygen migrates easily to the metal interface.

The logarithmic expression,

$$y = k_L \log(at + 1), \qquad (3)$$

associated with the most protective oxide layers, occurs less frequently; k_L and a are constants appropriate to the material and the test temperature.

In this logarithmic relationship the scale has certain electrical properties which, in addition to causing very high electrical resistance, virtually prevent diffusion at low temperatures. Cations, anions, and electrons can carry current in the scale. In general, the principal part of the current is carried by one of these charged particles. Theoretical studies of oxidation have demonstrated that to maintain electrical neutrality the charge must be carried by electrons and by one of the ion types. When the migration of positive ions is slow compared with that of the electrons, and the anions do not diffuse, the positive ions "pile up" in the film. The resulting positive field, called a space charge, opposes the further migration of positive ions into the film. The occurrence of a large space charge retards diffusion. When continued ionic flow is not possible because of the space charge a logarithmic law is followed.

N. F. Mott predicted the cubic growth law

$$y^3 = k_3 t \qquad (4)$$

from theoretical studies made in connection with the logarithmic equation (*Transactions* of the Faraday Society, Vol. 36, 1940, p. 472). He suggested this relationship for temperatures above 325° C., where the log-

*The parabolic equation is accurate for a flat surface, but different equations are appropriate for cylindrical and spherical shapes.

arithmic law could no longer be expected to hold — that is, where the space charge interferes less with diffusion.

Mott also predicted that a parabolic equation would result at high temperatures when diffusion is unimpeded by the space charge in the scale. Hence, the cubic law holds in a limited range of temperatures intermediate between those for the logarithmic and parabolic laws.

W. E. Campbell and U. B. Thomas were the first to observe the cubic law experimentally. In *Transactions* of the Electrochemical Society, Vol. 91, 1947, p. 623, they showed that between 125 and 250° C. copper oxidizes in this manner. Work done at the Los Alamos Scientific Laboratory indicates that both tantalum and titanium may follow the cubic equation throughout a narrow range of temperatures. This law has not been studied in detail, and it is premature to regard Mott's explanation as firmly established.

Typical curves for these growth laws in Fig. 1 show why the metals which corrode by the linear law are less desirable for high-temperature use, and why those obeying the logarithmic and cubic laws are the most desirable.

A graph of experimental data obtained at only one temperature can help determine which of the four equations represent such data best. The logarithm of the weight gain is plotted against the logarithm of the elapsed time. A straight line of characteristic slope results for the linear, the parabolic, and the cubic laws. These three equations (1), (2) and (4) can be represented by the general relation

$$y^n = k_n t. \qquad (5)$$

With this equation in logarithmic form

$$\log y = \frac{1}{n}\log t + \frac{1}{n}\log k_n \qquad (6)$$

it can be seen that the slope of the isothermal data is 1/n. The effect of an increase in temperature is to increase the value of k, and therefore to shift the line upward. As long as a single law is obeyed, a family of parallel lines represents the data for several temperatures.

The logarithmic law, however, cannot be put into the general form of equation (5). It leads to a concave curve on a log-log plot, as shown in Fig. 1.

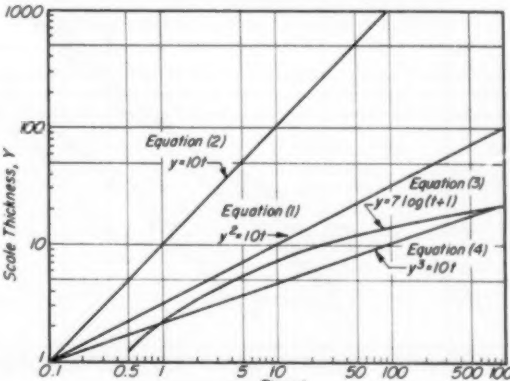
Pilling-Bedworth Ratio — In 1923 N. B. Pilling and R. E. Bedworth (in *Journal*, Institute of Metals, Vol. 29, p. 577) showed that certain metals oxidize linearly with time while others oxidize parabolically; they concluded that the relative volume of the oxide dictates the behavior. For example, the oxide of a light metal such as calcium is denser than the metal. The growing oxide occupies less space than the metal consumed, and therefore it is porous and under tension. Since metal oxides are generally not very ductile, fissure cracks are to be expected. Either pores or fissures offer easy paths for air to get to the metal, so the oxidation can proceed unimpeded. If, on the other hand, the oxide occupies more space than the metal from which it comes, the film will grow under lateral compression. As long as the film remains firmly attached it will be nonporous, and the reaction between the metal and gas will be controlled by diffusion through the scale. A parabolic law is therefore to be expected under such circumstances.

Pilling and Bedworth proposed that the ratio between the molecular volume of the scale (or oxide) and the volume of the equivalent number of metal atoms determines which law will be obeyed.

$$\text{P-B ratio} = \frac{M\rho_m}{\rho_c} \qquad (7)$$

wherein ρ_c is the density of the compound, ρ_m is the density of the metal, and M is the gravimetric factor for the oxide (gram-molecular weight of the oxide divided by gram-atomic

Fig. 1 — Log-Log Plots of the Four Equations Expressing Growth of Scale Thickness y With Time t. The value 7 was selected for the constant in the logarithmic curve in order to locate this curve between the cubic and the parabolic curves. The constant in the other three is 10



Pilling-Bedworth Ratio

weight of the number of metal atoms in the oxide). When the P-B ratio is greater than one, the oxide will be under lateral compression. Figure 2 shows that calcium, an ultra-light metal, oxidizes linearly with time, whereas copper, whose ratio is greater than one, follows the parabolic law.

Pilling and Bedworth discussed only the parabolic and linear laws. However, the logarithmic and cubic laws should be included in the P-B rule because of their growing importance. From the preceding discussion it is evident that either the logarithmic, cubic, or parabolic relationship can hold if the P-B ratio is greater than one, but only the linear law can apply if the ratio is less than one. The rule, however, provides no basis for deciding which of the three laws is applicable when the Pilling-Bedworth ratio is greater than one.

This concept of the P-B ratio has been useful in solving scaling problems, although a number of inconsistencies have been noted and it may be necessary to modify the hypothesis in the light of experience.

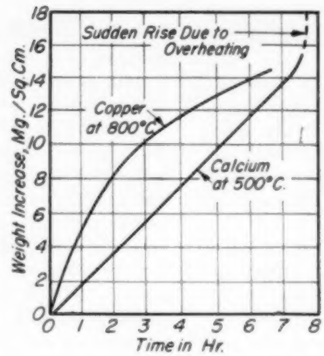
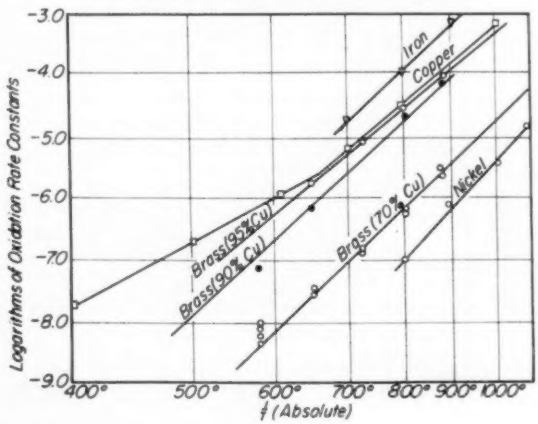


Fig. 2 — Growth of Oxide on Calcium at 500° C. (930° F.) Follows a Linear Relationship; Equation (2). Copper at 800° C. (1475° F.) follows a parabolic relationship; Equation (1). Note Cartesian coordinates rather than logarithmic as in Fig. 1. (After Pilling and Bedworth)

Fig. 3 — Arrhenius Plots of a Large Number of Results of Scaling Experiments at Various Temperatures. (After Dunn)



Effects of Temperature on Scaling Reactions — It has been indicated that the effects of temperature on scaling may be quite complex. It is true that scaling is either a chemical reaction rate process or a diffusion rate process. Both types of process conform to the Arrhenius expression:

$$k = A^{-Q/RT} \qquad (8)$$

where k is the rate or diffusion constant, Q is the magnitude of the temperature dependence (the energy of activation), A equals the constant frequency factor, R is the molecular gas constant, and T is the absolute temperature. Since this is an exponential equation, a straight line will result when log k is plotted against the reciprocal of the temperature.

J. S. Dunn was one of the first to apply the Arrhenius expression to corrosion data. Figure 3, taken from his paper in *Proceedings* of the Royal Society, Vol. III, Series A, 1926, p. 209, illustrates the straight-line character of several such graphs.

Assuming that equation (8) holds, a few determinations of constant k could be made at different temperatures, and the speed of the scaling could then be predicted over a wide range of temperatures by extrapolation. However, one cannot safely extrapolate data reported in the literature in this way, because the growth rate process is frequently dependent upon temperature. When the process changes, the temperature dependence also changes, and the Arrhenius plot does not consist of a single straight line. For example, Fig. 4 shows such an abrupt change in slope derived from a recent investigation. It indicates that titanium changes from the logarithmic to the parabolic law at about 360° C. Other examples of metals that demonstrate this change in growth process are listed in Table I.

Since the extrapolation of low-temperature data is not justifiable, the only safe procedure is to obtain experi-

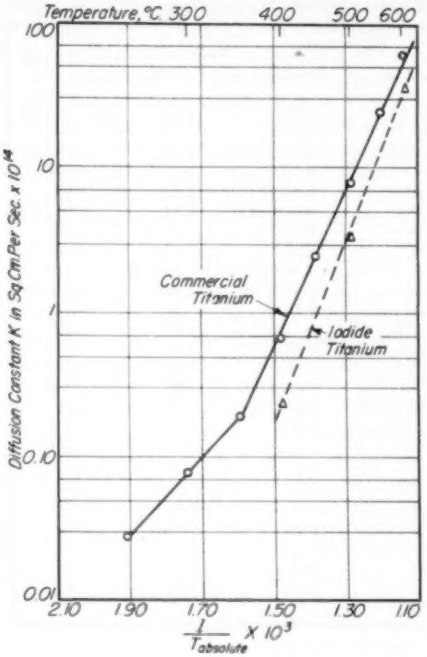


Fig. 4 — An Arrhenius Plot of Data for the Oxidation of Titanium Illustrates the Change in Slope Which Accompanies a Change in the Rate Equation. (After Gulbransen and Andrew)

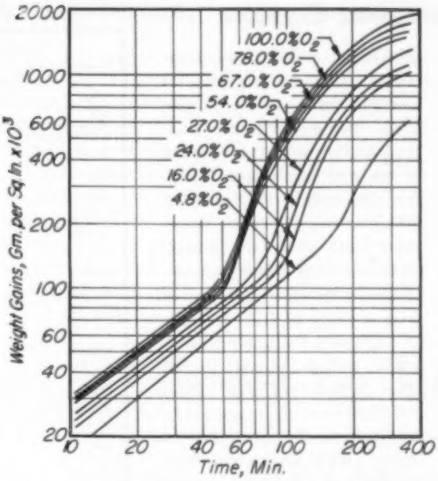


Fig. 5 — Log-Log Plot of Data on the Oxidation of Stainless Steel in Oxygen-Nitrogen Mixtures at 980° C. Illustrates That the Rate Law May Change During the Test. (After McCullough, Fontana, and Beck)

mental data in the range of temperatures anticipated in service.

Effects of Time — A less frequent occurrence is a change of growth law with time. In a study of the oxidation of tantalum at low temperatures, the rate appeared to be parabolic for 500 hr. For the same specimens over an entire 1500-hr. period a logarithmic law was found to be necessary.

H. M. McCullough, M. G. Fontana and F. H. Beck reported on "Formation of Oxides on Some Stainless Steels at High Temperatures" in *Transactions* ⊛, Vol. 43, 1951, p. 404. When heated in nitrogen-oxygen mixtures, the steel oxidized in a smooth linear fashion for several hours, after which the rate suddenly accelerated and later slowed down (Fig. 5). It is believed that the oxide ruptures after it reaches a certain thickness and the reaction speeds up because it is unimpeded by the thick diffusion layer.

Most of the examples already cited are deviations from the P-B rule. Pilling-Bedworth ratios for a number of pure metals and their oxides are given in Table II on the following page.

Aluminum, with a P-B ratio of about 1.3, would be expected to obey a parabolic law. (As already indicated, logarithmic, parabolic, and linear laws may be observed, one after another, as the temperature is increased.) Copper, which has a P-B value of 1.74, oxidizes by logarithmic, cubic, and parabolic laws. Iron is known to follow a logarithmic equation at low temperatures, but

Table I — Metals With Growth Laws Dependent Upon Temperature

Metal	Logarithmic	Cubic	Parabolic	Linear
Aluminum	<300° C.	—	300 to 450° C.	>500° C.
Calcium	—	—	330 to 385	>425*
Cerium	—	—	30 to 125	125 to 190
Copper	<50	80 to 250° C.	>250	—
Magnesium	—	—	<450	>475
Tantalum	<300	275 to 350	>350	—
Thorium	—	—	250 to 350	350 to 450
Titanium	<360	~360	360 to 820	>820
Uranium†	—	—	112 to 167	165 to 215
Zinc	<350	—	>350	—

*Accelerating period followed by a linear law.
†Above 215° C., attack accelerating with time.

Some Scaling Examples

parabolic at high temperatures. Lithium, despite its low P-B ratio of 0.566, follows the logarithmic relationship even in the vicinity of its melting point. Magnesium, with a P-B ratio of 0.785, follows first the parabolic and then the linear equation as the test temperature is raised. Titanium, with a value of 1.76, follows in sequence the logarithmic, cubic, parabolic, and linear laws. Stainless steel Type 304 follows a logarithmic equation near room temperature, and a linear equation at 980° C.

Four recent papers by D. Cubiciotti in *Journal* of the American Chemical Society (Vol. 73, 1951, p. 2028; Vol. 74, 1952, p. 577, 1080, 1201) give additional examples of growth laws changing from the parabolic to the linear type. He shows that calcium oxidizes parabolically in the region 330 to 385° C. Above 425° C. the oxidation follows the parabolic law for about 5 min. then accelerates and generally levels off to a linear relationship after an hour. Cerium follows a parabolic equation from 30 to 125° C. and a linear equation from 125 to at least 190° C. Cubiciotti believes that uranium follows a parabolic law in the range from 112 to 165° C. and a linear one from 165 to 215° C. Above 215° he noted an accelerating type of attack in which n is less than one. Thorium obeys a parabolic law in the range 250 to 350° C., and a linear one from 350 to 450° C. Of these 11 metals, only iron and copper seem to obey the rule for all temperatures.

Table II — P.-B. Ratios for Some Pure Metals and Their Oxides

Compound	Densities		Gravimetric Factor	P.-B. Ratio
	Compound	Metal		
Al_2O_3	3.5 to 3.9	2.702	1.89	1.31 to 1.46
Corundum	4.0	2.702	1.89	1.28
BeO	3.025	1.85	2.78	1.705
CaO	3.40	1.55	1.40	0.638
$Ca(OH)_2$	2.343	1.55	1.85	1.22
CeO_2	7.30	6.70 to 6.90	1.23	1.13 to 1.16
CuO	6.40	8.92	1.25	1.74
Cu_2O	6.0	8.92	1.13	1.68
FeO	5.7	7.86	1.28	1.765
Fe_2O_3	5.24	7.86	1.425	2.13
Fe_3O_4	5.18	7.86	1.39	2.12
Li_2O	2.013	0.534	2.14	0.566
LiOH	0.82	0.534	3.45	2.24
Li_3N	1.350	0.534	1.68	0.661
MgO	3.70	1.74	1.66	0.785
$Mg(OH)_2$	2.38	1.74	2.40	1.75
K_2O	2.32	0.86	1.21	0.447
SiO_2	2.32	2.4	2.14	2.21
Na_2O	2.27	0.97	1.35	0.575
Ta_2O_5	8.735	16.6	1.22	2.32
Tl_2O	6.0	11.85	1.01	1.99
TlOH	7.5	11.85	1.07	1.69
ThO_2	9.69	11.2	1.14	1.32
TiO_2	4.50	4.26	1.67	1.57
ZnO	5.47	7.14	1.245	1.62
ZrO_2	5.71	6.4	1.35	1.51

Iron and copper oxidize to form stratified layers of different oxides, and the proportion of each oxide changes with temperature. In these complex cases, the P-B ratio is satisfied. However, aluminum and magnesium violate the rule, although only one oxide of each is known. When simple cases do not obey but complex ones do, some doubt about the usefulness of the rule arises.

The alkali metals are ultra-light and therefore should oxidize by the linear law. Lithium, the lightest, is an excellent material for testing the validity of the P-B rule. Preliminary tests indicate that the behavior of lithium is anomalous. Although the P-B ratios for Li_2O and Li_3N are similar in magnitude, the reaction with oxygen is very slow, even at 100° C., whereas the reaction with nitrogen is very rapid at room temperature. At 146° C. in dry oxygen, a logarithmic growth law is observed.

In a study of the effects of dry nitrogen on lithium it was found that the reaction did not proceed smoothly over the entire metal surface, but spread from nuclei. Time lapse pictures are being taken in an effort to find out more about these phenomena. Although more work needs to be done, it appears that water vapor and oxygen inhibit the corrosion reactions of lithium. Thus, lithium seems to be quite different from most metals, which generally corrode faster in the presence of water vapor, and usually react with oxygen instead of nitrogen when exposed to air.

In conclusion, the idea that the ratio of the oxide-to-metal volume indicates whether scaling should take place by one growth law or another has proved to be only partially successful. Temperature and time have profound effects, not yet clearly understood.

Getting the Most From HAE Coatings

By M. Frager and H. A. Evangelides, Chemical Engineers, Frankford Arsenal, Philadelphia

THE HAE PROCESS electrolytically produces on magnesium or magnesium alloy surfaces a nonmetallic coating typically one to two mils thick (0.001 to 0.002 in.) that is both hard and very adherent. This process was developed at the Pitman-Dunn Laboratories Department of Frankford Arsenal, Philadelphia, and bears the initials of Harry A. Evangelides who is responsible for determining the key to its operation. Its combination of properties, including freedom from porosity, resistance to heat, and chemical inertness, warrants its consideration where magnesium is selected for design purposes.

This process has received public notice by means of previously published articles* and communications of the defense agencies and their contractors, both with the Office, Chief of Ordnance (ORDTB and ORDIS) and the Pitman-Dunn Laboratories Department. The ever-increasing number of requests for HAE specimens and HAE processing of components is obviously based on the outstanding properties of the coating. To the best knowledge of the research and development personnel at the Pitman-Dunn Laboratories, these coatings are unique when compared with any other treatment for magnesium and would seem to be in a different order of magnitude.

There have been instances where the HAE process has been applied to experimental components and assemblies without regard to the special properties of the coating, and consequently with disastrous results. For example, parts have been coated and exposed to salt spray without first being given one of the organic sealing treatments ordinarily recommended for high corrosion resistance. In such instances, when a few corrosion spots appear within 24 hr., the value of the coating is unnecessarily lowered in the judgment of the observers because they have heard of a 13,000-hr. salt spray resistance for HAE-treated objects. Another example is the poor corrosion resistance of experimental instrument assemblies: These were fastened with stainless steel bolts, without an allowance being made for the surface treatment which decreased the diameter of the tapped holes. Since there was a very close fit between the tapped holes and the bolts, before the coating was applied, distortion of the HAE-treated magnesium had to occur and resulted in exposed magnesium. Some distortion may have also occurred where the bolts were tightened excessively. Subsequent exposure of the assembly with its stainless steel – magnesium couples produced an early breakdown in the salt spray.

It is unusual that a material as hard and refractory as this coating should, at the same time, be as tough and elastic as — for example — a highly plasticized vinyl resin plastic. In one instance we are dealing with a ceramic-like substance; in the other with material having the ability to recover its original shape after being deformed.

In all probability, the reason magnesium has not been used more widely in spite of its availability and high strength-to-weight ratio is that it is so susceptible to damage by corrosion. In the Ordnance Corps a major premise of design is that material shall be able to withstand the most severe conditions likely to be encountered. It is believed that the HAE coating, because of the protection it provides, will add significantly to the number of applications for magnesium.

The HAE process provides electrolytically a coating which, if unsealed, enables wrought magnesium to withstand 20% salt spray exposures, without any corrosion being visually detectable, as follows:

	Alloy	Time to Failure
J-1	(6.5% Al, 0.15 Mn, 0.95 Zn)	90 hr.
FS-1	(3% Al, 0.20 Mn, 1.0 Zn)	26
M	(1.20% Mn)	Several

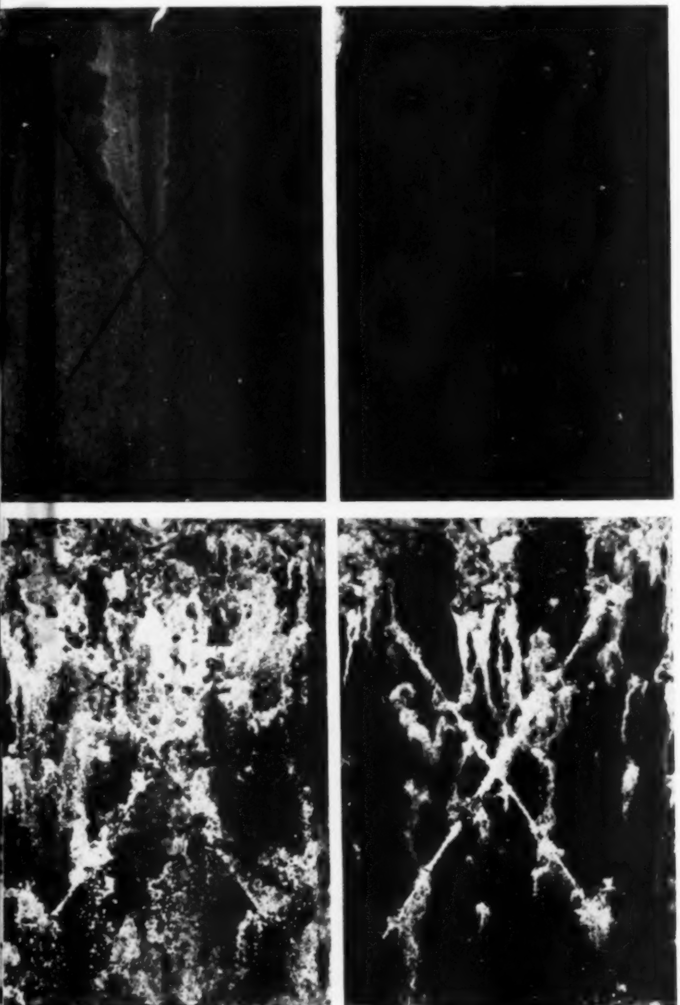
It is interesting to know that although typically there may be a few very small corrosion spots present at the time of initial failure, a continued exposure for several times the hours to failure does not increase their number. This indicates a certain amount of minimum porosity (some of

*Modern Metals, May 1951; Magazine of Magnesium, May 1951; Metal Finishing, October 1951; Organic Finishing, October 1951.

which may be attributable to a lack of homogeneity in the surface of the magnesium) and also indicates the chemical inertness of the coating.

In the evaluations conducted at the Pitman-Dunn Laboratories, the salt spray is used as a criterion of porosity for inert or cathodic coatings and as a measure of the weight per unit area of anodic metallic coatings. No exact correlation should be made as to the expected outdoor weathering resistance. However, since the coating functions primarily as a mechanical barrier, and the NaCl fog detects very fine porosity, there is good reason to expect long endurance for sealed HAE-treated magnesium used in outdoor exposures.

Fig. 1 — Results of 4900-Hr. Salt-Spray on Magnesium Panels Painted With Single Coat of Alkyd-Type Enamel. Top panels, HAE coating; bottom, standard dichromate



It is known that use of a suitable rust-preventive oil over phosphated steel represents a sort of synergistic action. That is, the resistance to corrosion of steel which has been phosphated and oiled is far greater than of the expected mathematical total of steel that has been phosphated and steel that has been treated with a rust preventive. So, too, with the HAE process for magnesium. This surface protection, plus a suitable wax seal, will withstand and has withstood a salt spray exposure of more than 13,000 hr. Similarly, instead of wax, zinc chromate primer or a phenolic finish over the HAE surface will give excellent results. For those applications where protected magnesium may be used in gears, a high degree of corrosion resistance exists because of the sealing action of the lubricant at the few pores in the coating. In addition, silicone greases have been used successfully. With all of these methods the effective work of sealing magnesium is done by minute amounts of sealant which close those few pores remaining in the HAE coating at the end of the process.

Dielectric strength of the coating at 60 cycles is about 550 volts, with a coating thickness of no more than 2 mils. This insulation value indicates a highly nonconductive and impermeable coating. Since the insulating quality is so high, it obviously should serve as an effective means of preventing galvanic coupling action, the bane of magnesium structures assembled with other metals. However, there are definite precautions which must be observed in using magnesium cou-

pled to another metal. These precautions are based on the fact that the hard, brittle nature of the coating, regardless of its impermeability, requires proper techniques for effective assembly.

The magnesium to be HAE treated should be in its final form and fully machined; that is, not require any operation which will bend or deform it. Nor should the metal be cut, drilled or ground after the coating has been applied. If the magnesium has been stamped, feathered portions should be deburred so that the coating is not applied unnecessarily to fragments of magnesium which may break off readily and expose bare metal. The preferred sequence for the cleaning of castings is to sand-blast the surface of investment materials and then machine prior to the HAE treatment. This is better than submitting a machined casting to sand-blasting, a procedure likely to damage finished surfaces. No prior chemical treatment should be applied to castings.

Since the coating is relatively impermeable, any break in it will produce more intensified corrosion at the damaged area than if no coating at all were on the magnesium. For this reason it is definitely a poor practice to have HAE-treated magnesium sheets drilled and riveted.

The more perfect the continuity of an inert or cathodic barrier over magnesium, the greater the corrosion susceptibility of the magnesium at any discontinuity in the coating. Furthermore, since all other metals used with magnesium are cathodic to it, a diminution in the area of exposed magnesium to that of any other metal involved in the assembly will also cause more attack of the magnesium. For this reason ferrous metals and copper-bearing alloys used with magnesium should be cadmium plated or zinc plated, and the plating chromated and organically finished to minimize the amount of cathodic metal exposed in a couple with magnesium.

Since riveting with 56S aluminum alloy rivets is such a common practice for the joining of magnesium, there are additional precautions which will help prevent galvanic damage. These are the use of zinc chromate paint, such as U. S. Army 3-201, Zinc Yellow Primer, at all faying surfaces prior to assembly, and the use of nonconductors, such as high-strength plastic laminates, to prevent contact of the metals. Limited tests at Frankford Arsenal have shown somewhat better and more consistent performance for the dried zinc chromate paint than for that wet at assembly. For maximum protection against galvanic damage, the metal joined to the magnesium should be insulated at the interface, and rivets should be insulated from the joined metals at the head and shank areas. Only the head of the rivet corresponding to the magnesium surface need be insulated with plastic or an aluminum washer if aluminum sheets are being joined. Consideration should be given to the danger resulting from the increase in diameter of the shank during the riveting operation. The deformation of the rivet hole in the magnesium should be held to a minimum. If the shank diameter of a rivet is increased excessively during heading, the coating at the perforation may crack and expose the magnesium. Judicious selection of rivet sizes and ample rivet hole diameters and the use of anodized soft aluminum washers against the HAE-treated magnesium will do much to prevent deformation of magnesium and insure that it receives maximum protection from the coating. Aluminum rivets of 52S alloy have performed better than 56S in tests involving couples of HAE-treated magnesium and painted steel, probably because of the lower yield strength and less magnesium deformation.

Results at the Pitman-Dunn Laboratories have shown clearly that there is inhibitive value in the use of a zinc chromate primer such as U. S. Army Specification 3-201. These results are based on exposures in the salt spray for specimens scribed through the organic finish and the HAE coating and into the magnesium metal. Where zinc chromate primer had been used, the amount of corrosion at the scribe was neglible. However, when the less inhibiting TT-E-485, Type II, alkyd-type enamel had been used, corrosion was found in the scribes as shown in Fig. 1. It is also interesting to observe that wash primers over HAE-treated magnesium have not performed as well as the zinc chromate primers. JAN-E-480, Type I, a heat-reactive phenol formaldehyde paint, has performed better than the TT-E-485, Type II. The former has a greater resistance to the alkalinity produced by the corrosion of magnesium.

A good paint system for the HAE coating, therefore, consists of one coat of the

3-201 primer and one or more top coats of JAN-E-480, Type I. The prime coat should be applied to a thickness of 0.4 to 0.7 mil, the top coats to a thickness of 0.7 to 1.2 mil. The excellent appearance of scribed specimens so prepared and exposed in the salt spray for 2000 hr. gave no reason to believe that the exposure could not be repeated for an equal length of time without failure.

The use of heat-reactive phenol formaldehyde varnishes complying with U. S. Army Specification 3-221 has also been very successful, even with films so thin that dimensional changes cannot be determined with micrometer calibers. The normal thickness for such films is 0.4 to 0.6 mil. Other paints are now being studied.

Just as zinc phosphate films on steel and aluminum oxide films on aluminum have been very helpful in preventing welding of these metals with steel punches and dies during drawing operations, so also the use of this coating may be beneficial for forming operations on magnesium. At least the HAE process would conform to the principle which is receiving increasing acceptance that a filler in a lubricant for a high-pressure application need not be dispersed in the lubricant but can conveniently be available at the surface of the metal being formed.

In experiments at the Pitman-Dunn Laboratories, preliminary results on the bonding strength between the HAE coating and the magnesium revealed that a force of at least 2500 psi. would have to be applied normal to the surface to separate the coating from the metal. In these tests a tensile machine was used to pull apart a specimen prepared by having a coated piece of magnesium interposed and cemented to steel grips. An epoxy resin cement was used as the adhesive. Since the adhesive value for cementing steel to steel was less than half of what it should have been, it is assumed that perfect alignment of the specimens did not exist during the determinations, and a value below the actual bond strength resulted.

The hard, inelastic nature of the HAE coating and its strong bond to the magnesium indicate that its best performance, from the standpoint of protection against corrosion and wear, can be expected from applications to rigid surfaces and not to those which will be cut, ground or deformed after the coating has been applied. Furthermore, the hardness of the coating (sufficient to abrade steel of Rockwell C-65) suggests its possible value as an abrasive material with the abrasive already bonded to a surface, the geometry of which can be varied at will. The coating, in addition to acting as a dielectric material, may also be of interest for possible capacitor and rectifier applications. Because of its poor thermal conductivity, the coating may also permit magnesium to be used where heat is involved and where magnesium with ordinary treatments would be adversely affected.

The coating is sufficiently thick (generally between one and two mils) so that the surface, which is a matte finish on removal from the electrolyte, can be polished and serve as a bearing where it would function similarly to jewels in certain mechanisms. Also, because of its inert nature, matte finish and strong bond with magnesium, the surface would appear to be ideal as a rententive base for elastomers such as neoprene and others requiring the use of a heavy organic coating. If an inert, adherent and hard coating is required according to a certain pattern, and bare magnesium can be tolerated at intervening areas, as possibly in an engraving or printing operation, the HAE coating suggests possibilities.

Tests on fatigue strength conducted for Frankford Arsenal by the National Bureau of Standards show that with magnesium specimens 94 mils thick and with a coating of 1.5 mils, there is a loss in fatigue strength of about 8% which, if corrected for the thickness of the coating, amounts to 2%. With a 40-mil magnesium sheet, there is a reduction in fatigue strength of 17% which, if corrected for coating thickness, is only 4%. These results are higher than those obtained for specimens with lower HAE coating thicknesses. Although an appreciable part of the loss in fatigue strength is attributable to the etching action on the magnesium surface at the interface during the formation of the coating, the results show that the effect on fatigue is rapidly lowered as the metal thickness is increased and also that thinner HAE coatings may be desirable for applications involving repeated flexure.

The authors express their appreciation to Lt. Col. D. J. Murphy and Messrs. C. C. Fawcett and E. R. Rechel for their encouragement and support of this development, and to William Blum, consultant to Frankford Arsenal, for his helpful review.

Atomic Energy Is Big Business*

FUNDS were appropriated by the Congress to the Atomic Energy Commission for the last four fiscal years as follows:

1949	\$ 621,900,000
1950	702,900,000
1951	2,032,100,000
1952	1,605,898,000

The initial appropriation for fiscal year 1953 amounted to \$1,137,727,000. To meet the demands of the expanding program in fiscal year 1953, the Congress made a supplemental appropriation of \$88,094,000 for operating and \$2,898,800,000 for plant and equipment.

Construction status of major production facilities was as follows:

Feed Materials Production Center at Fernald, Ohio, was partially complete and about 500 operators were already working.

24,000 persons were employed at the Paducah gaseous diffusion plant. The first units will be completed later than originally scheduled, but the last units will be ready for operation by the dates originally set.

37,100 persons were employed at the Savannah River project [principally on excavation, concrete work and steel erection].

Monthly construction costs, excluding the expansion program [authorized by the 1953 supplemental appropriation], are expected to reach a peak in September 1952 and will then amount to about 5% of the total monthly costs for all construction in the United States.

Further Expansion — On July 15, 1952, the President signed an act appropriating \$2,898,800,000 for expansion of plant and equipment. A considerable portion will be used for additional production of uranium^{235}. Additional gaseous diffusion plant capacity is scheduled to be added at the existing Oak Ridge, Tenn., plant, at the Paducah, Ky., plant under construction, and at a plant at a new site (with necessary supporting facilities at each). A major item for each of these expansions is electric power generating and transmission capacity. The annual power consumption at the new site, for example, will be more than the 1951 consumption of New York City. Expanded production of plutonium will be by the construction of additional reactors at Hanford, Wash. [operating], and Savannah River [under construction].

Employment — Direct employment by the A. E. C. increased from 5750 on Jan. 1 to approximately 6500 on June 30. Employment [by various contractors] in operations, research and development increased from 52,400 on Jan. 1 to about 56,000 on June 30.

During the fiscal year \$17,500,000 was allocated for biological and medical research in A. E. C. installations. Approximately \$5,800,000 was spent on 325 research contracts in universities, colleges and private laboratories.

Military Application — A large part of the total effort continued to be directed to the military aspects of atomic energy. Production of atomic weapons proceeded steadily. Research yielded new developments; these improvements were applied to the design of specific weapon models to meet the various needs of the armed forces. Construction of several new facilities progressed satisfactorily. Details of this work are enumerated currently in classified [secret] reports to the Joint Committee on Atomic Energy of the Congress.

Reactor Development† — The materials testing reactor at the testing station in Idaho was operated in May at full power. It will subject to intense radiation those materials considered promising for the construction of new reactors.

The keel was laid for the first nuclear-powered submarine. Construction of the prototype of the submarine thermal reactor and power plant [for this vessel] continued at the reactor testing station in Idaho. Westinghouse Electric Corp. is the prime contractor. This reactor power plant is being assembled in a section of the submarine hull.

Construction of a land-based prototype of the submarine intermediate reactor and its power plant was started by the General Electric Co. near Schenectady. It will be contained in a spherical steel building 225 ft. in diameter.

Four industrial groups have surveyed reactor technology, and Dow Chemical Co. and Detroit Edison Co. were the first to report. They proposed jointly financed research on the [commercial] feasibility of a dual-purpose reactor for producing both fissionable material and electric power. Details of a letter of agreement are now being negotiated. Work by the two companies, estimated at \$275,000 excluding overhead, will be carried on in their own laboratories. Much of the A. E. C.'s supporting studies are already in progress or budgeted.

Air Contamination — A phenomenon peculiar to atomic detonations is the fall-out of minute radioactive particles from the resulting atomic cloud. Most of it occurs within the target area, but some is picked up by wind and deposited throughout the country. An extensive nation-wide monitoring system consists of sample-collecting stations and mobile monitoring teams both on ground and in air. [As a result of such monitoring after explosions in Nevada] it can be stated categorically that at no time in any part of the country outside the controlled testing grounds has radiation been harmful to humans, animals, or crops.

*Verbatim extracts from "12th Semiannual Report of the U. S. Atomic Energy Commission", July 3, 1952.

†Some details as to size, power, and type of these reactors are listed in *Metal Progress* for July 1952, p. 106.

By E. J. Dulis and G. V. Smith, Research Laboratory, United States Steel Co., Kearny, N. J.

Effect of Cold Work on Sigma Formation

The effect of cold work on sigma formation in two austenitic stainless steels, Types 310 and 347, during exposure at 1300° F. for up to 5000 hr. was investigated by hardness and microscopic examination. Behavior of these steels in several annealed conditions was described in a paper on "Effect of Prior Treatment on Precipitation of Sigma Phase", by G. V. Smith, E. J. Dulis and H. S. Link, *Welding Journal*, Vol. 30, 1951, p. 385s. Chemical composition of the steels is shown at the bottom of the column. Type 310 was tested as air cooled from forging temperature, and after cold drawing 36%. Type 347 was water quenched from 1975° F., and cold drawn 41%.

Microstructures and estimated percentages of sigma after various times at 1300° F. are shown on the opposite page, and the amount is related to time in Fig. 1 at right. With but a few exceptions in the 25-20 Cr-Ni steel, the massive particles in both steels are sigma and the small particles carbide. In the 25-20 steel sigma started to form rapidly, amounting to 0.7% after 20 hr. in the as-received condition, and 10% after 20 hr. in the cold drawn condition (micros for 20 hr. not shown).

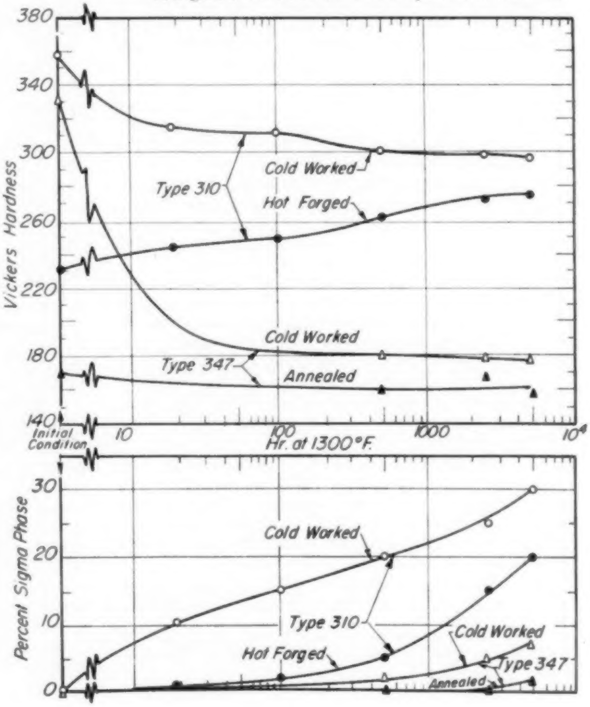
Sigma formation is enhanced by cold work (Fig. 1). Smaller and more numerous particles indicate that the effect of cold work is to form additional nuclei for subsequent sigma growth. This increase in sigma nuclei explains why the effect of deformation can persist after recrystallization occurs.

The hardnesses of both steels are also related to time of exposure at 1300° F. in Fig. 1. The 25-20 steel (Type 310) that had not been cold worked showed an increase in hardness with increasing sigma, but the cold worked steel decreased in hardness with longer time at 1300° F. Clearly, two opposing forces are at work in the initially cold worked metal — a softening owing to recovery and recrystallization and a hardening because of precipitation of sigma; softening is the dominant force.

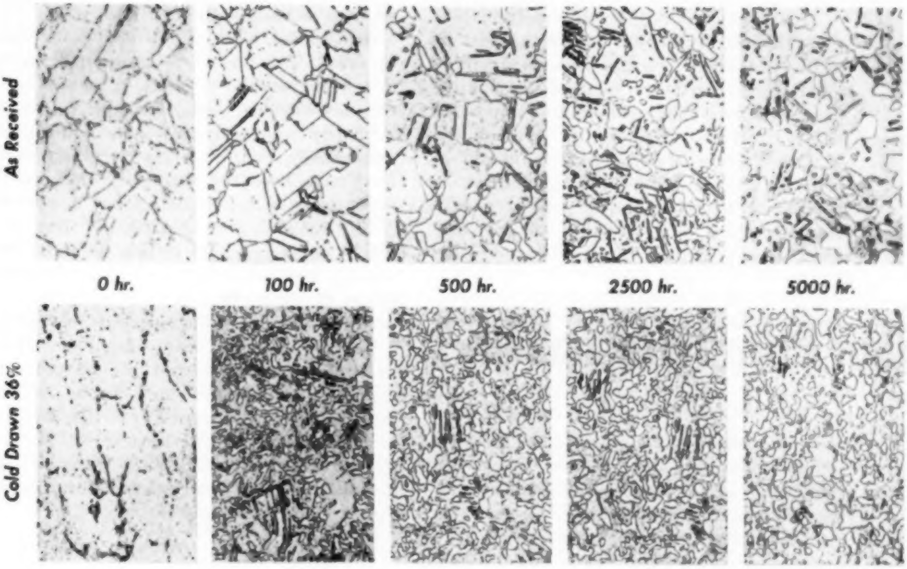
In the 18-8 Cb steel (Type 347) the quantity of sigma formed was quite small and presumably affected the hardness only slightly, if at all. The hardness of the initially cold worked metal fell off rapidly with time as a result of recovery and recrystallization.

	Type 310 (25-20 Cr-Ni)	Type 347 (18-8 Cb)
Carbon	0.07%	0.07%
Manganese	1.81	1.21
Phosphorus	0.024	0.014
Sulphur	0.013	0.018
Silicon	0.53	0.43
Nickel	22.20	10.80
Chromium	27.24	17.10
Columbium	—	0.89

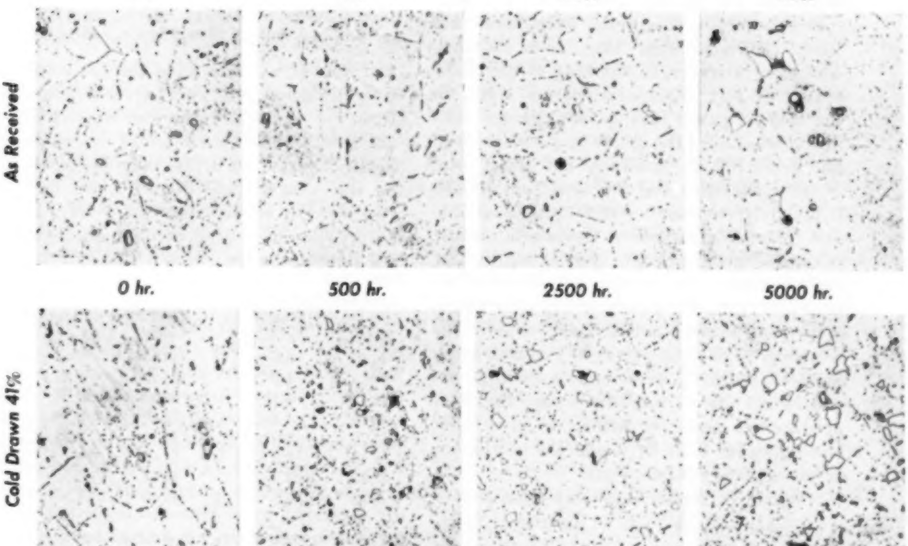
Fig. 1 — Relationship of Hardness and Quantity of Sigma Formed to Time of Exposure at 1300° F.



Sigma in 25 Cr, 20 Ni



Sigma in 18 Cr, 8 Ni, Cb



By Harry W. McQuaid, Consultant, Cleveland*

What Price Hardenability?

Alloy steel has been most widely investigated and discussed during the past 50 years; thousands of pages have been printed about apparently every detail of the making, processing and application of this important material. I say "apparently" because the literature seems strangely lacking in data on some of the most important factors which govern its selection and application — economic factors which should govern any given alloy addition. To the steelmaker the economic factors of alloy selection are seen in one light, to the alloy producer in another light, and to the purchaser, designer and processor in still another light.

The average alloy steelmaker — especially the openhearth operator — if he had his way, would probably be inclined toward the nickel-molybdenum combination, or perhaps the chromium-nickel-molybdenum combination. He would avoid the straight manganese and the silicomanganese steels like poison, and would be just as well pleased if the lower-carbon straight chromium steels were not used. The governing criterion is the cost. The steel producer, in thinking of the desirability of any given combination, adds up the various extras and special charges until he has assembled the total charges as-shipped and from this he subtracts his grand total of labor, material, and overhead, and decides that a given combination of alloys is desirable and interesting according to the relation the calculated profit bears to that of other alloy combinations. He is often influenced by pressure from the customer or alloy salesman — but usually not for long. Due to the relatively high alloy extras he can charge on the nickel-bearing steels and to the high recovery of nickel from the scrap, the steel producer is perfectly willing to give them more support than he would the chromium or manganese combinations.

Whatever is done, the alloy extra should be the first concern of the automotive metallurgist. It has been my observation that the average so-called technical man is not concerned enough with the delivered costs of the product. This has always been a handicap to him because, in the eyes of management, the metallurgical department is concerned primarily in supplying a product which processes easily and performs well, but these qualities are all too frequently obtained by expensive material, treatment, and inspection. If the metallurgical department were primarily concerned with getting the most economical final product which was good enough to get by in the field, it would probably be better considered in the eyes of management.

If we study the alloy extra list we find that extras have developed in a hit-and-miss way. If we take the same carbon content and classify steels according to the amount of alloy extra charged by one well-known steel producer (not necessarily standard) we arrange the lower-cost openhearth steels as shown in the following list:

Steel	Type Composition	Alloy Extra
1340	1.75 Mn	14.00
5140	0.80 Cr	17.00
4042	0.25 Mo	19.00
8640	Triple Alloy*	26.00
4140	0.95 Cr, 0.20 Mo	27.00
3140	1.25 Ni, 0.65 Cr	33.00
4640	1.85 Ni, 0.25 Mo	40.00
6140	0.95 Cr, >0.15 V	44.00

*0.40 to 0.70 Ni, 0.40 to 0.60 Cr, 0.15 to 0.25 Mo.

Now if we determine the hardenability by calculating the "ideal critical diameter" from the analysis, we find an entirely different order as listed at the left of the tabulation below. Next if we divide the alloy extra cost by the ideal critical diameter, we find the relative cost of the alloy extra for hardenability per inch of critical diameter as in the right of the list:

Hardenability		Cost of Hardenability	
Steel	Critical Diameter	Steel	Relative Cost
4140	5.3 in.	4140	5.08 per in.
8640	4.3	5140	5.87
6140	4.1	8640	6.02
3140	4.0	1340	6.10
5140	2.9	3140	8.25
4640	2.8	6140	10.20
1340	2.3	4042	10.55
4042	1.8	4640	14.30

If we select an alloy steel on the basis of hardenability and try to get the most for our money in hardenability, the logical steel,

*The second portion of a talk, entitled "Economics in the Selection of Alloy Constructional Steels", given May 12, 1952, before the "Old-Timers' Night" of the Detroit Chapter, ⊕.

at least to start off with, would be the chromium-molybdenum grade (S.A.E. 4140), with the straight chromium (5140) and the low-chromium-nickel-molybdenum (8640) not too far behind. 4140 and 8640 will harden to the center of a 5.3 and 4.3-in. round, respectively, under ideal conditions.

But you might ask yourself, "Why would anyone want so much hardenability? S.A.E. 4042, the straight molybdenum steel with critical diameter of less than 2 in., has ample hardenability for nearly every automotive purpose, as proven by its very successful application to the Chrysler products."

As a matter of fact, the shallow hardening of the S.A.E. 4042 is a most desirable advantage, since it insures the minimum of quenching stresses which add to the service stresses and are a major factor in the failure of heat treated parts. It also, for the same reason, insures the minimum of distortion in heat treating and thus has definite advantages over the deeper hardening steels. Its alloy extra is not too high, and because it is a good performer it should appeal to steel buyer, heat treater, and metallurgist alike.

Now, if S.A.E. 4042 has enough hardenability for so many automotive parts, even though it has the lowest hardenability of the entire list, then the S.A.E. 1340 and the S.A.E. 5140 (the steels with the lowest alloy extra) must also have ample hardenability, but obviously we are not selecting steels on the basis of hardenability alone. I would advance the proposition, however, that if these lower-cost steels, when properly heat treated, have enough and uniform hardenability, it is foolish to spend money for *extra* hardenability, especially since it is usually reflected in extra machining costs as well.

What we should really be seeking is the cheapest oil hardening alloy combination that is available, and the logical place to look for it is in the S.A.E. 1300, 5100 and 4000 series. Our object is to get something that is good enough to get by satisfactorily in the customer's hands, and we should not spend a cent in getting anything better than that. With the improved, more rigid designs of mechanical devices, better surface and more accurate contacts of today's gears and other frictional parts, we can evaluate much more closely the working stresses in service; with the improved control of hardenability and heat treatment we can feel much more certain of uniformity of the final product; all this means that we can work closer to minimum requirements and cheapest steels.

The affection of the steel producer for a given alloy, like that of the alloy producer, is naturally influenced by the net return he gets for his efforts in supplying it, and this return is governed by the cost of producing the alloy grade and the price he gets for it. In the early days of alloy steel, when nickel was the key and almost only alloy used, the price of the nickel-bearing alloy steels was relatively very high; the alloy extra, plus the high recovery of nickel in the scrap, plus the excellent support of the alloy producer, made the nickel steels a great favorite with the steelmaker.

The nickel-chromium steels introduced a little later represented one of the best combinations and proved popular with the steelmaker, the alloy maker and the user. This was especially true in the lower-priced medium-carbon S.A.E. 3100 series. The straight nickel steel was well advertised and was widely used in rear-axle gears and other highly loaded gears, and the low nickel-chromium type was put into axle shafts and transmission gears, although for some very heavy-duty applications the high (5%) nickel and nickel-chromium (Krupp) types were retained. Because of the high stresses due to lack of rigidity in the earlier designs of bearing supports, and poor finishing and inaccuracy of contact surfaces, many makers of heavy-duty gears could find nothing quite so good as these very expensive nickel and nickel-chromium grades of specially heat treated alloy steel.

With improvement in design and the increase in automotive volume production and competition, pressure became heavy for steels which processed more easily and cost less. The straight chromium steel quickly reached a high position because of its lower costs and good performance, but it was not looked on with favor by the average steel producer because of the low alloy extra and the low recovery of chromium in the scrap. Its only real friends were the steel buyer and the producers of chromium.

The late C. H. Wills was a most important figure in the early development of tonnage alloy steel, especially in the openhearth. He was directly responsible for the "selling" of alloy steel to Henry Ford, who designed and built the Model T around the properties which could be had from chromium-vanadium

steel. I have always felt that Wills' contributions in the advancement of alloy steels have been much overlooked.

This development, nearly 50 years ago, of aluminum-free chromium-vanadium open-hearth steel deserves study by anyone interested in the economic bases of alloy steel selection. Here we have an alloy combination which gives us about as much for the money as any ever proposed. It had the right balance of manganese, chromium and silicon to make it harden in oil sufficiently deep to insure minimum quenching stresses. When vanadium was added in sufficient amount to insure a fine grain in the already "normal" steel, we had a carburizing steel which could be directly quenched from the box (or furnace) and still show a good fracture and minimum distortion.

Advantages from the steelmaking standpoint resided in a combination of silicon, manganese, chromium and vanadium. The last mentioned was a rather inactive deoxidizer, so the iron oxide in the steel was high enough to produce the proper kind of sulphides in the microstructure. In the finished bar we have a steel with the highest ratio of transverse to longitudinal properties, and one which will form (in the fully quenched portions) the nearest approach to 100% martensite and, when carburized, produce a "normal" grain boundary.

As was pointed out in the first part of this article (*Metal Progress* for August 1952, p. 104), the sulphide type must be controlled if we are to get the full value of the costly alloy. In fact, this control by proper melting and deoxidation is a much more important factor in the processing and performance of a given heat treated alloy steel part than is the actual alloy itself! These relationships were worked out after much difficulty in the production of the original aluminum-free chromium-vanadium steel for Ford by Harold Wills. Eventually, they had a steel corresponding to the present S.A.E. 6100 series of the fine-grained normal type.

We can find little in the alloy steels of today which is any improvement over the desirable combination developed in these early Cr-V steels. They had just about the right hardenability when oil quenched for any automotive or tractor gear or shaft; when carburized they could be direct quenched because they were inherently fine grained; they machined better in the normalized condition than the nickel-base alloy steels; they had unusually good transverse properties and superior impact value.

It is therefore not surprising that these chromium-vanadium steels were highly successful. They were used in springs, in gears, in drive shafts, in rear axles, and even in connecting rods and front axles, in crankshafts, in many bolts and other minor applications. In fact, the Ford Model T contained more alloy steel parts than any automobile since then, and did more to encourage the use of alloy steel than any other product.

ONE ALTERNATIVE: STRAIGHT CR STEEL

At the time of its introduction, the principal competition to Cr-V steels came from S.A.E. 2300 (3.5% Ni) and 3100 (1.5% Ni, 0.65% Cr). Before the days of grain-size control the aluminum-free chromium-vanadium fine-grained type (with its ability to be direct quenched from the carburizing temperature and its simplified heat treatment) had a great advantage over these two. It was then also a lower-priced steel and would normally have replaced them except that it was tied in directly with Ford and Dodge and therefore not particularly desired by competitors in the automotive industry.

In devising an alternate, the natural step was to drop the vanadium from the Cr-V mixture. The coarse-grained straight chromium steel (S.A.E. 5100) was soon demonstrated to be practically interchangeable with Cr-V when melted and rolled under the right conditions, except that, for best results, carburized parts required a double heat treatment. But it was considerably cheaper (containing no expensive vanadium), easy to process, and equal in every way when properly made and treated to the more costly competitive steels. It was soon giving a good account of itself in roller-bearing rolls, gears and other parts. It still is today the equivalent of practically any competing alloy steel for automotive applications.

One of the advantages of the S.A.E. 5100 series as compared to the nickel-containing steels of 25 years ago was that the latter were commonly made with much lower manganese. As has already been emphasized, manganese is a big factor in determining the type of sulphide precipitate and its resultant effect on conditioning, banding, machining and ferrite in the as-quenched martensitic

C. H. Wills

The late Childe Harold Wills came as near to being chief engineer of Ford Motor Co. in the Model T days (starting 1906) as any man could be in that organization without titles. Wills convinced Henry Ford that there was nothing like chromium-vanadium steel. Ford had examined the bent axles and other parts of a wrecked European racing car. He had been told that they were made of "alloy steel" and they appeared to be exceptionally tough, so he plumped for the vanadium steels then being promoted by the Englishman, J. Kent-Smith. John McConnell and Fred Griffiths made them at United Steel Co. in Canton. Wills also installed complete metallurgical laboratories at Highland Park and studied many other steels — particularly, during World War I days, the molybdenum steels supposed to be responsible for the superiority of German ordnance. When Wills joined Chrysler Corp. in 1933 he brought much pressure to bear on steel manufacturers to make the straight molybdenum steels with special attention to "normality", grain size and hardenability, and in this way he had an important influence in bringing this analysis to its present widespread utility.

A citation "for early development of chromium, molybdenum and vanadium steels and their application to automobiles" is ample indication of Henry Chandler's status among the pioneers of the automobile industry. This citation accompanied the presentation of an ⊕ Distinguished Service Award for Meritorious Contributions to Progress in Alloy Steel in 1948. Chandler joined the research laboratory of Ford Motor Co. in 1914 to direct the metallurgical section under Harold Wills, who was in general charge of research and engineering. He brought with him a most unusual educational background gained from studies at University of California, M.I.T., the Sorbonne (Paris), and the Polytechnic Institute of Zurich. Working with up-to-date equipment and a capable staff, Wills and Chandler laid the groundwork for these new alloy steels of great potentialities. When Wills resigned to design and build the Wills-St. Clair car, he took his team-mate along as chief metallurgist. In 1924 Chandler became assistant to president of Vanadium Corp. of America, and is now a vice-president whose duties are still to promote the development and use of alloy steels.

Henry T. Chandler

structure. In gears and bearings, subjected to highly concentrated rolling contact, the addition of nickel and molybdenum increases the tendency to retain undesirable austenite. The harder, more wear resistant martensite containing chromium (with its lower internal compression stress when properly heat treated) provides the best structure for the contact surface of bearings and gears.

It is for this reason that the straight chromium steel is practically universal for ball bearings. It has exactly the same qualifications for roller bearings and gears, and in my opinion it has been overlooked by the automotive metallurgist, especially in view of its favorable price. Someone will rise to say that the straight chromium steel will have low impact properties at 40° F. below zero and it needs vanadium or nickel or molybdenum or a combination of all to give good subzero toughness. How important the impact values at −40° F. are in the performance of automotive equipment is hard to say, although possibly on the Alcan Highway and for winterized ordnance they may be very important; apparently there has been no special complaint on ball bearings. Ordinarily straight chromium steel of the right type, made fine grained with aluminum, will have satisfactory subzero properties — but if any-

thing must be added it could probably best be 0.10% vanadium.

The fine-grained straight chromium steels require a certain definite melting technique to insure maximum properties — but this takes no more care than other grades. However, even when normal variations in melting and rolling practice are accepted, the product will compare most favorably with any steel in a price class any way close to it. Thousands of tons of it in various types have been used in transmission parts, in springs and in bearings. Because of its price it should be by far the greatest tonnage alloy steel in use today.

MEDIUM-MANGANESE STEELS

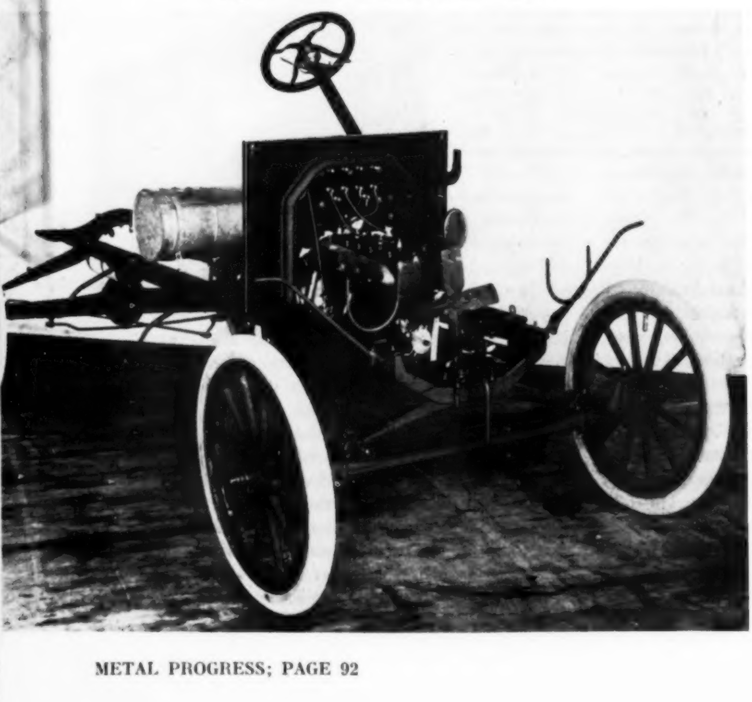
If we look at the alloy extra list we find one type which is still cheaper than the straight chromium. This difference amounts to approximately $3.00 per ton and is in favor of the S.A.E. 1300. This has 1.5% manganese, enough so its hardenability ranks with several other oil hardening steels. When properly made and treated, S.A.E. 1300 will perform in an automobile gear and axle as well as any standard alloy steel commonly used. It involves considerable difficulty in melting, especially in the openhearth furnace; missed heats due to off-analysis are common, and in practically every steel mill it shows little if any profit and is considered undesirable business. (It is important to a large steel purchaser and processor that his selection of steel permit the steel melter to show some reasonable profit; otherwise, the mill production departments are being continually pressured to cut costs and this generally only intensifies the rejections and troubles with the delivered product.)

When we think of the work which was done under Bob Schenck's direction at Buick some years ago with the S.A.E. 1300 series, and the thousands of tests which proved its good machinability, satisfactory heat treatment and good performance, it is hard to understand why its use did not spread. It did tend to vary in hardenability from heat to heat and its cause was naturally not helped by anyone in the steel industry.

Straight manganese steel needed most careful melting to insure uniformity in machining and reaction to heat treatment, and therefore was criticized in the automobile plant somewhat. The addition of "Grainal", with its vanadium and boron, gave this steel properties of the highest order, as did separate additions of molybdenum, or boron, or vanadium. It is a steel which is best suited to electric-furnace single-slag melting practice, but has been priced on the assumption that it is to be melted in the openhearth.

The S.A.E. 1300 alloy steel in the low-sulphur grades (priced to make its production interesting in the modern electric-arc furnace) may someday become of the greatest commercial importance. If we purchased steel only on the basis of its physical properties at a given hardness, it would be difficult to keep the S.A.E.

Fig. 1 — Chassis of 1914 Model T Ford



1300 series out of first place. A relatively small addition of boron, molybdenum, or vanadium improves its hardenability and its uniformity in processing. S.A.E. 1300 plus boron — for example, the recently approved A.I.S.I. 14B35 to 14B52 — will give a very good account of itself and will probably be very highly considered if ever a really determined attempt is made to arrive at the lowest-cost steel for general applications. The trouble is that the extra for boron is enough to make the S.A.E. 1300 grade with boron more expensive than S.A.E. 5100 or 4000 steels, and it would therefore be ruled out of consideration.

MOLYBDENUM IN ALLOY STEELS

After the first world war the use of molybdenum began to be advocated, and Cr-Mo, Ni-Mo, and Ni-Cr-Mo types were introduced and given favorable comments.

The Cr-Mo analysis (patented by Wills and Chandler and becoming the 4100 series) proved to be a most desirable steel, especially in the medium-carbon grades. In the lower-carbon ranges it was generally of the coarse-grained type and because of its high hardenability showed a much greater tendency to warp than the Cr-V steels during carburizing and other heat treating.

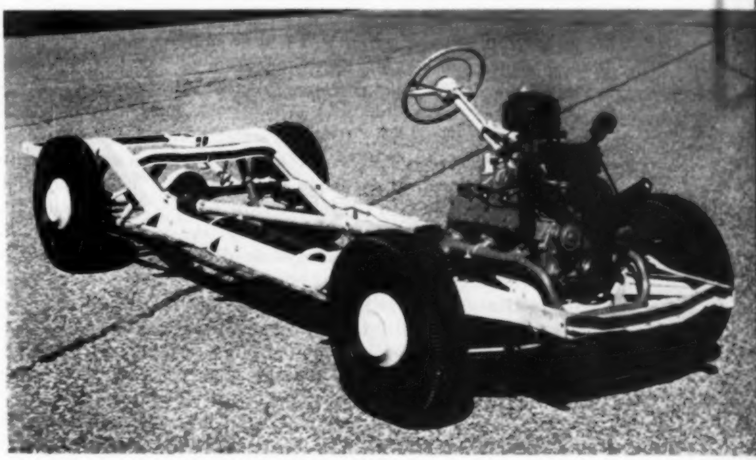
Because it was lower in price, 4100 soon displaced the widely used nickel-chromium (3140 and 3130 grades) to a large degree and was a big factor in the success of the molybdenum-producing companies and those receiving royalties on the steel. It was not especially well liked by the steel producers because of the lower alloy extra and the variation in its hardenability with grain-size variation. Due to the relatively high manganese and chromium in combination with molybdenum, it offers more hardenability for the dollar than any other commonly used automotive alloy combination, as shown in the tabulation on p. 88; in fact, the greatest criticism of this steel is that it offers too much hardenability. Thus we have in the S.A.E. 4100 series economical alloy steels of great merit and wide application with an alloy extra which appeals to the steel buyer but not very much to the steel producer.

The S.A.E. 4140 has merit in large axle shafts and heavy sections and, if fine-grained and heat treated to best advantage, can replace most of the highly alloyed steels such as Ni-Cr-Mo 4340. It requires careful quenching and handling in heat treatment. In the low-sulphur grades it has general application in heavy sections, such as in the oil-production field and farm-implement field. It could with some modification of analysis and treatment serve in any constructional alloy steel application where economy would justify it.

THE NICKEL-MOLYBDENUM COMBINATION

In the nickel-molybdenum S.A.E. 4600 series, we have a steel originally produced for Studebaker and patented by Woodside and Dawe. It was at first especially applied to rear-axle gears and other carburized parts and was designed to replace the straight 3½% nickel S.A.E. 2300. Like 2300, the present nickel-molybdenum series appeals to steelmakers because of the alloy which can be recovered from scrap, but they did not especially encourage its use to replace the straight nickel steel because of the high alloy extra and the well-established openhearth

Fig. 2 — The 1952 Ford Chassis



Timken Promotes 4600

practice which had been worked out for the more profitable S.A.E. 2300. Naturally the nickel producers did not like to see the lower-nickel replace the higher-nickel steels and so it took some time to convince the automotive industry that this was a logical step.

Quite a story could be written around the competitive situation which influenced the introduction of the 4600 series broadly into the automotive industry. At first it was a battle between the new Timken Steel and Tube Co. and the older alloy steel producers. At about the same time, Timken Roller Bearing Co. was faced with the problem of changing water hardening carbon steel in its bearing cups and cones to an oil hardening alloy steel in order to meet a similar move by competitors. Up to this time the Timken rolls had been made from plain chromium steel with very good results and it would seem that the logical step would be to go to the S.A.E. 5100 for the whole bearing.

The prime factor in going to the nickel-molybdenum steel for Timken bearings was that Timken had its own steel mill and approximately 85% of the ingot made for bearings came back to the furnaces as scrap, either as steel-mill, tube-mill or bearing-factory scrap. A very elaborate briquetting layout was engineered for almost 100% recovery of bearing-plant scrap, and an electric-furnace practice was worked out which gave the nickel-molybdenum analysis a uniform, extra-low-sulphur, fine-grained, normal structure and quality of cleanliness desirable in the best grade of bearing steel. All this was combined with a recovery of nickel and molybdenum in the scrap which was sufficient economically to justify the adoption of the S.A.E. 4600 for Timken roller bearings.

Furthermore, the 4600 series was superior in nearly every way to the 2300 series for rear-axle gears, especially since at the time it was introduced it was made in the fine-grained type and (in the electric-furnace grade) was $5.00 per ton cheaper than the openhearth S.A.E. 2300. It could be direct quenched from the carburizing box with very little distortion, and with lower first cost, lower machining and heat treating cost and better gear performance it soon displaced the 3.5% nickel openhearth steel which was being advocated by other alloy steel producers.

I can speak with some authority on this point, for I moved from Canton to Detroit in 1926 with specific instructions that I was to prove to the automotive world that in every way the Timken electric-furnace S.A.E. 4600 was far superior to the openhearth S.A.E. 2300 then standard in ring gears and pinions. This was easy to do, but it would have been a different story if the competition had been S.A.E. 6120. The chromium-vanadium steel was fine grained, machined well, and could be direct quenched and cost little more, but it lacked friends in the steel plant and was hardly considered.

After the competing mills learned how to make the steel fine grained and satisfactorily clean at the same time, they produced a passable grade of nickel-chromium S.A.E. 3120 in the openhearth, but by that time it was too late and 4600 was firmly established. Thus we can summarize the S.A.E. 4600's story by saying that it was able to displace 2300 and 3100 in the carburized gear field (and also in the higher carbon field) because it was deliberately priced so that the electric-furnace 4600 was cheaper than the openhearth 2300 and — being fine grained and of better than openhearth quality — it simplified the machining and heat treating operations and gave a better final product.

Here it would be well to pause long enough to praise the designers of automotive equipment and of machine tools for cutting surfaces of extreme accuracy. At the time the 4600 Ni-Mo series was being introduced, great and successful efforts were made to improve the design so that accurate contacts and mountings could be maintained under any normal load encountered. Elastic action of metal under load was given much more consideration, as was stress concentration, inherent stresses, decarburization effects, lubrication and other mechanical details which affected operation. As far as performance of automotive gears is concerned, my experience would indicate that improvements in design, mounting and maintenance of carefully developed and initially accurate contacting surfaces were by far the most important contributing factors.

The alloy in the steel and the details of its heat treatment — after we had learned to obtain the required wear resistance (hardness) without excessive change of shape — are of minor importance. Today it is safe to say that the cheapest combination of sound steel that can be made with the proper control of hardenability and that can be processed at the least final cost is the logical choice.

Some of the best gears ever made were those made at Buick from the T-1300 straight manganese steel. In fact, some of the best properties I have ever seen in any steel were obtained in heat treated T-1300 steels which had "Grainal No. 1" added in the ladle. Any experienced metallurgist could truthfully say the same of the S.A.E. 4000 series, the 5100, the 6100 series and many other types.

And so I return to my oft-stated belief that the metallurgist is, after all, primarily interested in the alloy combination which will give him the cheapest final product that will quench out (when necessary for the requirements of an important machine part) as nearly to 100% martensite as possible — providing a sufficient amount of carbide is present and is of the right type to insure satisfactory resistance to wear. With the modern design and superior accuracy and finish of contacting stressed parts, his job is much easier than just a few short years ago when a gear even in the best application would move 0.010 in. under an endurable overload.

Robert B. Schenck

Credit for development and exploitation of the manganese steels in automotive history goes to Bob Schenck and is appropriately recorded in his ⊕ Distinguished Service Award. He got his hand in on their production in the years 1909 to 1914 when, with a degree from Lehigh University, he worked as foreman in the armor plate department at Carnegie Steel Co.'s Homestead Works. After a brief period as metallurgist for Erie Forge Co., he went to Flint, Mich., as chief metallurgist for General Motors Axle Division, and in 1917 became chief metallurgical engineer for Buick Motor Division. At Buick he resumed his interest in the pearlitic manganese steels, and it was largely through his efforts that they were eventually standardized as the S.A.E. 1300 series. Schenck retired a year or so ago, but put in some pretty strenuous days last fall as a tour escort and technical advisor for a group of foreign engineers participating in four weeks of plant visits as a preliminary to the World Metallurgical Congress in Detroit.

THE "AMOLA" STEELS

These considerations of design and finish are appropriate to introduce a few final remarks about the 4000 series ("Amola") steels established, despite passive resistance of steelmakers, by C. H. Wills for the Chrysler Corp., and also the "triple alloy steels" forced upon industry by alloy shortages during World War II.

The S.A.E. 4000 series (often spoken of as straight molybdenum steels, although the manganese is enough higher than average for them to be more truly known as manganese - molybdenum steels) should be most interesting to any large user of alloy steels for applications such as we have in the automotive industry where shallow hardening steels are desirable. In spite of its low "ideal critical diameter" (1.8 in.) the "Amola" steels have demonstrated an ability to perform equally as well as the higher and more expensive alloy steels they have replaced.

If necessary, the manganese-molybdenum steels could replace all other alloy grades of alloy steel for constructional application. This is a rather broad statement but it is defensible. They could even be used for many ordnance parts. I can remember distinctly making an experimental heat of T-1340 to which had been added 0.25% of molybdenum for hardenability effects and 0.10% of vanadium for fine grain size and high transverse properties. Care was taken to get the sulphur down and to exclude aluminum from the heat and we had no difficulty in demonstrating that its physical properties were in every way equal to the regular high-nickel-chromium-molybdenum-vanadium steel in the making of medium-size guns during the last war. The manganese-molybdenum steel also showed up just as well in firing tests, and in every test, from melting to firing, proved to be as good as the high-alloy guns.

It would seem to the unprejudiced seeker

after the truth that the Chrysler "Amola" series has very important possibilities, but how much is due to the special "normality" tests imposed in the specification and how much is due to a standard melting practice* is a little hard to say. It is certain that combinations of manganese and molybdenum with or without vanadium are of the greatest interest up to the point where they cost more than the chromium and chromium-vanadium steel — and this statement applies to any other type which will be good enough for the given application and not cost any more. Again I say that the cost (to the user) should be the basic criterion of choice, and this would be affected by machining and heat treating costs in the final summation.

THE TRIPLE ALLOY STEELS

During the last war the S.A.E. 8600 series was developed by the steel industry primarily as a means of saving alloys. In this it was highly successful. Also its Mn-Ni-Cr-Mo combination is well suited to openhearth melting, gives good recovery of residual elements in the scrap, and is priced to insure a little profit in even the highest-cost steel plants. It has more than enough hardenability for any automotive application and is competitive in price with the S.A.E. 4100, but costs more than the S.A.E. 5100, 4000, and 1300 steels. It lends itself to openhearth or electric-furnace melting, as far as hitting the analysis is concerned, and in normal times its alloy is provided in a large part from the scrap. In my opinion, it is one of the best alloy steel types available today and its use should be encouraged. How successful it will be will depend on how much the competition from lower-cost types of automotive steel can affect its position.

The S.A.E. 8600 series was developed primarily to save nickel for armament and other war needs. During the present rearmament and stockpiling program there is even some discussion about replacing nickel in ordnance because of its scarcity. This seems a little illogical when a simple step would be to convert the nickel-containing gear and bearing steels used for civilian purposes to the cheaper chromium or manganese-molybdenum types. The nickel so saved would certainly take care of the gun, shot, and armor-plate needs and help meet the wartime demands for stainless.

SUMMARY

Better design of alloy gears, shafting and other automotive parts, together with greatly improved mountings to eliminate harmful stress concentration due to deflection under load, and with more accurate manufacture and finer surface finish, have greatly improved the service life in the past 15 years. This has resulted in very much less accent on the importance of basic alloy composition, so that the available lower-cost, lower-alloy grades can, with the highly developed heat treating control now available, be used interchangeably in automotive applications.

The shallow hardening manganese-molybdenum ("Amola") steels in Chrysler cars have demonstrated that there is more than enough hardenability in any of these steels and that more than the minimum hardenability is really undesirable. The straight chromium S.A.E. 5100 series, the manganese-molybdenum S.A.E. 4000 series, and the medium-manganese S.A.E. 1300 series will be the logical tonnage steels of the days ahead, principally because they are, over-all, the most economical.

Small additions of boron and similar elements to increase the hardenability will be perhaps warranted in a few applications, but it is difficult to prove that additional hardenability is needed except where the quenching facilities are poor. Where transverse properties are especially important it would be better to get it in the steel mill by controlling the deoxidation with silicon and manganese, eliminating the aluminum and using vanadium to get the highly desirable "fine grain normal" structure.

The demand for "quality" grades of tonnage low-alloy steels which will require specified types of sulphide inclusion in addition to a fine grain will increase the demand for very low-sulphur steels. This will be met in days to come by improved methods of sulphur reduction and by the use of a sulphur-free charge. When the really low-sulphur, fine-grained steels become economically available, a new day will dawn, metallurgically speaking, in the thinking of what constitutes quality in automotive steels.

*Much of the success in working a low-hardenability steel depends upon the uniformity of melting practice and the uniformity from heat to heat of the type of sulphide inclusions.

GIANT NICKEL STEEL SHAFT... installed as a replacement on a 54" crusher, to assure maximum service life for The International Nickel Co., at Copper Cliff, Canada. Overall length 21'6", maximum diameter 3'8", bore 6".

How Nickel Helps a Crusher PUT THE SQUEEZE ON COSTS

Many forgings are so large that only part of the mass can be worked under the press before the steel has to be reheated. These large sections of steel, typified by this crusher shaft, so limit the cooling rate as to make liquid quenching ineffective.

Consequently, improved strength, hardness and other properties that prolong life of large forgings are much more dependent upon wise selection of alloy content than is the case with small forgings.

Because of these facts, the large crusher shaft shown above was forged from a 160,000-pound ingot of 2¾ per cent nickel steel... produced, rough-turned and heat-treated by the Bethlehem Steel Company, and finish-machined by the Traylor Engineering Company of Allentown, Pa.

After normalizing and tempering, two tests on longitudinal specimens, taken from a prolongation at mid-radius, averaged as follows:

Tensile Strength	80,000 p.s.i.
Yield Strength	51,000 p.s.i.
Elong. in 2"	28.0%
Red. of Area	58.3%

The strengthening effect of nickel on ferrite is independent of carbon content or heat treatment of the steel, and its effectiveness in reducing the rate and temperature of the upper transformation, induces better response to the necessarily milder heat treatments used.

Nickel alloy steels may help you obtain peak performance from vital parts of *your* products or equipment. Send us the details of your problems for our suggestions. Write us now.

At present, most of the nickel produced is being diverted to defense. Through application to the appropriate authorities, nickel is obtainable for the production of engineering alloy steels for many end uses in defense and defense supporting industries.

EMBLEM OF INCO SERVICE

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N. Y.

Approximate Critical Temperatures for Steels

By Laboratory of Central Alloy District, Republic Steel Corp. In most instances found by examining microstructure of quenched ⅜-in. disks of 1-in. round, taken from furnace at 20° F. increments. Grain size of steel unknown. Rate of heating and cooling about the same as in furnace-cooling for commercial annealing.

Type No.	On Slow Heating		On Slow Cooling		M_s, °F. (a)
	Ac_1, °F.	Ac_3, °F.	Ar_3, °F.	Ar_1, °F.	
Carbon Steels					
C1010	1335	1610	1560	1260	—
C1015	1335	1580	1525	1250	—
C1020	1335	1555	1500	1260	—
C1022	1335	1555	—	1260	—
C1025	1340	1545	1470	1250	—
C1030	1340	1495	1450	1250	—
C1035	1340	1475	1425	1255	—
C1040	1340	1455	1400	1255	675
X1040 *(b)*	1340	1450	1340	1270	—
C1045	1340	1435	1385	1260	—
X1045 *(b)*	1335	1420	1330	1270	—
C1050	1340	1415	1365	1260	610
X1050 *(b)*	1335	1400	1330	1270	—
C1055	1340	1390	1350	1260	—
X1055 *(c)*	1335	1400	1330	1270	—
C1060	1340	1375	1340	1265	555
C1065	1340	1350	1325	1270	—
X1065 *(c)*	1335	1380	1330	1260	—
C1070	1340	1350	1310	1275	490
C1080	1345	1355	1290	1280	415
C1095	1350	1415	1340	1290	—
Free Cutting Steels					
B1112	1355	1660	1560	1250	—
C1118	1345	1520	1495	1245	—
C1120	1335	1550	1510	1255	—
C1137	1315	1420	1360	1220	—
C1141	1310	1400	1340	1210	—
X1315 *(d)*	1345	1520	1495	1245	—
X1330 *(d)*	1320	1490	1380	1240	—
X1335 *(d)*	1315	1420	1360	1220	—
X1340 *(d)*	1310	1400	1340	1210	—
Manganese Steels					
1320	1335	1510	1375	1190	740
1330	1325	1470	1350	1170	675
1335	1330	1440	1340	1160	640
1340	1320	1430	1330	1150	610
T1345 *(e)*	1315	1410	1300	1160	—
T1350 *(e)*	1310	1400	1225	1105	—
Nickel Steels					
2015 *(e)*	1375	1575	1450	1215	—
2115 *(e)*	1345	1525	1475	1195	—
Nickel Steels (cont.)					
2317	1295	1425	1340	1110	725
2320 *(e)*	1285	1420	1235	920	—
2330	1280	1375	1190	1040	625
2340	1275	1355	1190	1050	555
2345	1275	1345	1190	1060	525
2350 *(e)*	1280	1340	1180	1070	—
2515	1285	1400	1220	825	690
Nickel-Chromium Steels					
3115	1355	1500	1470	1240	770
3120	1350	1475	1455	1230	730
3130	1345	1450	1380	1230	660
3135	1340	1435	1350	1220	630
3140	1355	1410	1330	1220	590
X3140 *(e)*	1350	1430	1300	1240	—
3141	1350	1410	1335	1230	580
3145	1355	1395	1300	1220	545
3150	1355	1380	1275	1210	510
3215 *(e)*	1350	1465	1415	1350	—
3240 *(e)*	1330	1400	1310	1220	560
X3250 *(e)*	1340	1375	1255	1200	—
E3310	1330	1435	1240	1160 *(f)*	655
Molybdenum Steels					
4023	1350	1540	1440	1240	775
4027	1350	1520	1420	1230	745
4032	1350	1495	1390	1225	715
4037	1345	1475	1370	1210	680
4042	1340	1440	1330	1210	650
4047	1340	1440	1330	1200	615
4063	1340	1400	1260	1190	505
4130	1395	1490	1390	1280	685
E4135	1395	1475	1380	1280	—
4140	1380	1450	1370	1280	595
4150	1370	1410	1350	1280	530
4320	1335	1490	1380	1140 *(f)*	720
4340	1335	1425	1310	1210 *(f)*	545
4608	1310	1570	1385	1170	850
4615	1340	1490	1400	1200	780
4620	1330	1475	1380	1190	755
4640	1315	1430	1300	1150	605
4815	1275	1415	1310	800 *(g)*	725
4820	1260	1410	1260	760 *(g)*	685
Chromium Steels					
5045	1300	1450	1370	1290	600
5046	1335	1420	1350	1220	620
5120	1410	1540	1470	1290	760
5130	1370	1490	—	1280	690
5140	1360	1450	1340	1280	620
5150	1330	1420	1280	1220	555
E52100	1340	1415	1320	1270	485
Chromium-Vanadium Steels					
6115 *(e)*	1420	1550	1450	1300	—
6120	1410	1545	1440	1300	760
6125 *(e)*	1400	1490	1390	1295	—
6130 *(e)*	1390	1485	1370	1285	—
6135 *(e)*	1390	1480	1370	1280	—
6140 *(e)*	1390	1455	1375	1295	—
6145	1390	1450	1375	1290	580
6150	1385	1450	1375	1270	545
Triple-Alloy Steels					
8620	1350	1525	1415	1220	745
8625	1350	1485	1390	1220	710
8630	1355	1460	1370	1220	680
8635	1350	1450	1345	1225	640
8640	1350	1435	1325	1230	610
8645	1350	1430	1310	1230	575
8650	1350	1420	1295	1210	545
8660	1345	1410	1270	1230	485
8719	1350	1540	1430	1220	745
8720	1350	1530	1420	1220	740
8735	1355	1455	1350	1220	640
8740	1345	1435	1330	1220	605
8745	1345	1425	1315	1215	575
8750	1340	1415	1310	1210	540
9255	1400	1500	1380	1320	585
9260	1400	1500	1380	1315	550
E9310	1310	1495	1285	1070	685
9440	1330	1420	1280	1190	610
9445	1325	1400	1265	1180	570
9763	1330	1370	1280	1230	485
9840	1340	1420	1260	1200	575
9850	1330	1405	1270	1210	510

NOTES — *(a)* M_s temperatures (martensite start) are calculated for the mean composition ranges.
(b) Low-manganese varieties of S.A.E. steels (General Motors' specifications).
(c) High-manganese varieties of S.A.E. (General Motors') specifications.
(d) Low-manganese resulphurized varieties of 13xx series, S.A.E. list (General Motors' specifications).
(e) S.A.E. (General Motors') steels.
(f) On cooling at somewhat faster rates a split transformation may occur.
(g) Split transformation.

Substitution of Straight Chromium Stainless Steels for Chromium-Nickel Types

Established Uses of Straight Chromium Stainless Steels

BALTIMORE, MD.

Most of the recent publications dealing with the substitution of straight chromium for chromium-nickel stainless steels have centered around applications using flat rolled products such as sheet and strip. Long before the current restrictions on the use of nickel, the straight chromium grades were widely used in the form of bars and wire for a variety of applications. Since this experience goes back over many years, it should be instructive to review briefly in what type of applications they have had success, where they have shown particular advantage, and where they have shown certain limitations.

In Table I are listed some of the outstanding applications of the 400 series. This list is far from complete but it does illustrate typical bar and wire uses.

Types 403, 410, and 416 have been very satisfactory for forged and machined parts and can be heat treated to develop a wide range of tensile strength and hardness. They have been used primarily for applications requiring high strength coupled with moderate corrosion resistance. They have been highly satisfactory in contact with steam, gasoline, and similar mild environments. In the atmosphere or immersed in river water they are subject to rust staining but corrode at very slow rates. These alloys have good creep strength up to about 950° F. and will resist destructive scaling up to 1200° F.

Types 420, 420-F, 440-C, and 440-F are highly hardenable alloys and in the hardened condition exhibit good resistance to sterilizing solutions and to most foods. Practically all cutlery is now made from Type 420 or modifications of it; such steels are particularly useful for cutting tools and in applications requiring resistance to wear and abrasion. Because these steels are softened if heated above 950° F., they are not commonly used for heat resistance.

Types 430, 430-F, and 446 are not hardened significantly by heat treatment and are used in the annealed condition. Trays made of Type 430 wire have given excellent service in dishwashers, refrigerators, and like applications. The grade has been widely used in food handling equipment and for various cold headed products such as screws and nuts. Stainless steel trim is commonly attached with Type 430 fasteners. Type 430-F is widely used for machined parts in food processing equipment. Both grades have good resistance to scaling up to 1500° F. Above about 900° F. they do not possess as high strength as the chromium-nickel grades and this should be considered if they are substituted for 18-8.

Type 446 has excellent resistance to corrosion and in some environments may be superior to 18-8. It has been used primarily in heat resisting applications since it will resist scaling up to about 2000° F. It has low notch toughness and welds tend to be brittle. In many bar and wire applications, however, this is no detriment and the alloy deserves consideration for applications where highly corrosive media are met.

In general, the straight chromium stainless steels can be forged without difficulty and the sulphur-containing grades, par-

Table I — Illustrative Uses of Straight Chromium Bars and Wire

Type	Nominal Analysis % C	Nominal Analysis % Cr	Established Uses
			Group I — Hardenable, Martensitic
403*	0.10	12	Steam turbine blades, jet engine air compressor blades, rifle gas chambers.
410	0.10	12	Trash racks in dams, coal stoker parts, wet gas well valves.
416†	0.10	12	Fine instrument parts, water pump shafts, golf club heads.
420	0.30	13	Cutlery, drive screws for metal storm sash, medical instruments, plastic molds.
420-F†	0.30	13	Paint spray nozzles, self-tapping screws, milk bottling machinery parts.
440-C	1.00	17	Surgical bone cutters, aircraft propeller bearings, oil well check valves, fuel nozzles.
440-F†	1.00	17	Pickle-packing machinery, can-closure rolls, meat-grinder blades.
			Group II — Nonhardenable, Ferritic
430	0.08	17	Dishwasher and refrigerator trays, textile loom parts, fasteners, gas range grates.
430-F†	0.08	17	Beverage bottling parts, oil burner nozzles, food mixer parts.
446	0.10	27	Molten salt bath electrodes, glass annealing conveyer racks, thermocouple wells.

*Turbine quality.
†Sulphur or selenium added to these grades for machinability.

ticularly Types 416 and 430-F, have very good machining properties. These grades can be machined at rates considerably higher than are possible with the chromium-nickel types. Types 410, 420, and 430 are very well suited for cold headed products. They do not harden with cold work nearly as much as the chromium-nickel types and Type 430 has been preferred to 18-8 for severely upset parts such as recessed head screws.

F. K. Bloom
Research Metallurgist
Armco Research Laboratories

N.P.A. Regulation M-80 Lists Many Approved Uses for Chromium Stainless

New York City

As to just where and under what conditions the substitution of the straight chromium types for the nickel-bearing stainless steels can be made, the Metallurgical and Conservation Branch of the Steel Division of the National Production Authority has made tremendous strides in this direction during the last nine months. As a result, the N.P.A. has published Order M-80, Schedule A, which contains four long lists of stainless steel products which do not permit the use of nickel. This gives quite an impressive list of items, and except for the railroad car item (which involves a special combination of high strength, welding and corrosion properties), it has been mutually agreed by the stainless producers, fabricators, and users that all items listed can be properly formed and welded from the straight chromium steels, and that these steels have satisfactory corrosion resistance for these applications. However, these items deal mainly with stainless steel products such as those related to automotive and building materials, household appliances, laundry and hospital equipment, which are usually subjected to atmospheric or mildly corrosive conditions. It is in this field that the major portion of nickel has been conserved in stainless steel uses to date.

Conservation of nickel in stainless steels used in the process chemical industries presents a more serious problem. We have had approximately 25 years of experience in this field with the use of straight chromium steels for construction materials used for mild or strong oxidizing conditions. For example, nitric acid of all concentrations is made in Type 430 equipment which includes extremely large, welded pressure vessels. Concentrated nitric acid has been transported in all-welded 8000-gal. tank cars for the last 20 years. There are also many applications involving a combination of oxidizing and reducing conditions where Type 430 stainless steel is entirely satisfactory. If the corrosive condition is mainly reducing in action — either the general (over-all solution) or local pitting types — it is very unlikely that the straight chromium steels can be substituted for the nickel-bearing grades. In any event, any substitution that is made for the more severe corrosive conditions of the chemical industry must be based on experience or service tests.

G. A. Sands
Electro Metallurgical Co.

Limited Uses of Type 400 Steels Laid to Lack of Incentives

Milwaukee

Prior to the period of nickel shortage there had not been too much incentive to use the straight chromium grades in tubular products because the price differential was relatively small. In addition, ductility and manipulation requirements frequently favored the improved properties found in Type 304.

Generally speaking, we have also often resorted to up-grading in the selection of the proper alloy for certain applications. This is true for many uses where Type 430 could be substituted for Type 302, or even 304. However, if any doubt existed, we selected the higher grade. This was often because of our reluctance to learn to use less easily worked or fabricated grades.

Of all of the Type 400 series alloys, the Type 430 seems to offer most advantages as a substitute. In addition, a 430 grade has been developed using titanium, which has improved the ductility of welds. This has permitted an acceptable welded tube when made by the conventional fusion methods. This grade has responded particularly well to inert-gas-shielded welding practice.

The lower chromium (12%) Type 410 has more limited corrosion resistance and has air hardening properties that are frequently objectionable. Type 442 (21% chromium with 1% copper) could be studied for a number of applications. We have been producing this in tubular form for a number of years for a heat resisting application which has been very successful. It has higher corrosion and oxidation resistance than 430 but is limited in high-temperature strength when compared with the nickel-chromium grades. Type 446 (25 to 30% Cr) offers excellent high-temperature oxidation resistance but poor high-temperature strength. It also introduces difficult fabricating and production problems in many items.

Summarizing, it appears that Type 430 and Type 430 modified with titanium offer considerable promise for many applications. However, it is strongly recommended that in considering any substitution the matter be thoroughly considered from all angles and that competent help be solicited before substitutions are made. While my company has not had much occasion to substitute, in view of the urgent demand for the nickel-chromium grades of tubing for critical defense work, doubtless many normal applications could be considered for such substitution.

Elmer Gammeter
Director of Laboratories
Globe Steel Tubes Co.

Urges Wider Use of Chromium Stainless Alloys

University, Ala.

I believe that there is a very large field where the chromium-iron alloys may be used to replace the 18-8 alloys during this period of acute nickel shortage. In fact there has already been such a trend; the production of the chromium alloys has surpassed the chromium-nickel varieties for the past two years.

In the early days of the use of these alloys, many fabricating difficulties retarded their adoption. It was soon discovered that the austenitic types were much more ductile, better for welding and more easily fabricated than the chromium varieties. Since the final fabricated cost at that time was similar for both kinds, it was natural for consumers and equipment fabricators to specify the 18-8 type. However, as the users of these stainless grades became more familiar with their characteristics and their applications, many of the fabricating headaches were overcome and, for the past ten years, it has been possible to buy equipment made from either type of alloy.

There is no doubt in my mind there are innumerable places where the more common 18-8 alloy may be displaced with plain chromium alloys. Some of these are tabulated below:

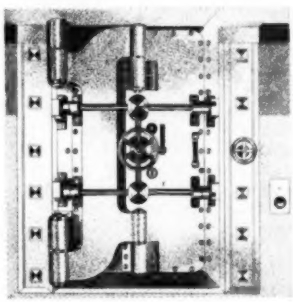
1. Household appliances such as sinks, stove tops, ash trays and many other gadgets where corrosion is mild.
2. Food processing and handling equipment, soft drink barrels, counter tops, restaurant equipment, tanks, sheet-type pasteurizers, pumps and other miscellaneous canning apparatus.
3. Oil refining equipment, tanks, still tubes, return bends, pumps and piping. (The 5 to 9% chromium still tubes are now standard.)
4. Architectural and ornamental materials such as spandrels, plaques, railings, spouting and building sheets.
5. Automotive applications involving body trim and hardware, as well as other uses in this field.

It seems possible that at least 50% of the applications where 18-8 alloy is now specified may be considered as potential possibilities for the use of straight chromium alloys. From a consumption of 300,000 tons per year of chromium-nickel alloys, a possible saving of about 50% of the nickel requirement might be achieved. This would amount to 15,000 tons of nickel annually.

The substitution of the straight chromium materials will cause some redesigning to conform to the different properties of the substitute and also a considerable change in the fabrication operations. The greatest difficulty will probably arise in complicated weldments and assembly practices; a reduction in the amount of welding may need to be considered. It will also be much more difficult to get satisfactory tubing and pipe in the chromium alloys because the manufacture of this kind of tubing has always been much more troublesome in the welded or seamless variety.

Knowing that many of the problems related to this substitution have already been overcome, it seems obvious that a much larger effort should be made to increase the use of the straight chromium alloys so as to further conserve the very strategic metal, nickel. I believe that the use of nickel in steel should be restricted as much as possible to those high-temperature applications where it has a specific value and where it is known that none of the nickel-free alloys are of value.

E. C. Wright
Head
Dept. of Metallurgical Engineering
University of Alabama



Many Uses Where Corrosive Conditions Are Not Severe

Motherwell, Scotland

The question of the substitution of 18-8 type stainless steels by those of the 400 series is one which cannot be answered without having very detailed knowledge of the exact requirements which the component is expected to meet. These requirements include, among many others, the corrosive medium, the method of fabrication and the degree of corrosion which can be tolerated. Bearing in mind these limitations we can, however, make certain generalizations on the problem.

Many applications for Type 400 steels are to be found in the food processing industries where the use of stainless steel is dictated by the desire for appearance and cleanliness rather than by the severity of the corrosive conditions. As an example of applications where these steels may be used due to the fact that a certain amount of corrosion can be tolerated, one can mention pump impellers, hydro-electric turbine runners, and ship propellers.

Very large quantities of steel similar to Type 431 are used in this country. It has a corrosion resistance only slightly less than that of 18-8, together with good mechanical properties. Unfortunately, it presents difficulties in working and is generally not available in bar form or as castings. The hot working properties of the 400-type steel are generally superior to those of the 300 series, but the 400 series is definitely more difficult for forming operations involving cold working. The straight chromium stainless also presents fewer difficulties in casting and machining than do the steels of the 18-8 type.

R. Hunter
Deputy Managing Director
Clyde Alloy Steel Co., Ltd.

Substitutions Based on Knowledge of Metal and Application Are Successful

Pittsburgh

Since the demand for nickel has again exceeded the supply, the chromium stainless steels have been widely substituted for the austenitic 18 Cr, 8 Ni varieties such as 302. Many of these substitutions have been quite successful, particularly those which were made with a full appreciation of the requirements of the application and the inherent properties of the straight chromium steels. Investigation of those instances where trouble has been encountered reveals that the steels had been asked to do the impossible.

For example, the austenitic types, particularly 301 and 302, can be cold worked to high ten-

Fabrication Techniques

sile strengths and yet retain good ductility. The ferritic grades, such as 430, do not have this characteristic. Types 410, 420 and 440, however, can be hardened by heat treatment. Welding techniques have been well established for the chromium-nickel grades but welders need help when they are asked to join the less familiar chromium types if brittle welds are to be avoided. The ideal procedure in welding 430 involves a preheat at about 300° F., a postheat at about 1400° F., and hot-peening of the weld metal. Obviously, this cannot be done in every instance, but special techniques or chemistries may be recommended depending upon the application involved.

Type 302 has remarkable toughness even at subzero temperatures, whereas 430 does not. On the other hand, the straight chromium grades do not have the high coefficient of expansion and low thermal conductivity which sometimes are a disadvantage in the chromium-nickel steels. The straight chromium steels, due to their lower ductility, were not considered as well suited for deep drawing as the 18-8 types; with proper rolling practice and correct die design and lubrication, 430 has been drawn into articles which surprised even the most optimistic "experts".

Corrosion resistance comparisons are not quite so well defined, since it is difficult to measure this property accurately. Conditions vary so much that "Yes" or "No" statements are avoided. It can be said that under many circumstances, particularly those which involve oxidizing rather than reducing conditions, straight chromium steels are as satisfactory as the nickel-bearing stainless. By the same token, in some uses where 430 has not performed adequately, it is likely that 302 would also have failed.

Each individual application must be considered on its own merits. Nonnickel-bearing stainless steels can be used quite successfully when the recommendations of our experienced metallurgical engineers are followed.

D. W. Kaufman
Metallurgist
Crucible Steel Co.

Fabricating Difficulties Being Overcome

Schenectady

Recent removal of C. M. P. controls from the straight chromium stainless should encourage stronger efforts by designers and manufacturers toward the successful application of these steels in fields heretofore restricted to the alloys of the 300 series.

While it is generally true that the popular 18-8 offers greater resistance to corrosion than the 12 or 17% chromium of the 400 series, there are no doubt many applications where the straight chromium would, if tried, give satisfactory service.

The heat treatable steels of the 400 series have long been used successfully for numerous applications such as turbine blades, fan blades, motor and pump shafting, gears, cutlery, and even kitchen utensils. Many of these applications were tried and proved before the introduction of Cr-Ni steels about 1925.

Among the steels of the 400 series, the 17% chromium alloy (Type 430) is the one most frequently suggested as a replacement for the 18 chromium – 8 nickel alloys. This alloy has been satisfactory for a variety of applications in the field of corrosion and heat resisting service. Successful applications are shelves for refrigeration cabinets, refrigerator ice trays, bolts and screws, parts for measuring instruments, kitchen utensils, window frames, and decorative trim.

Strange to say, this steel is less frequently discarded because of inferior resistance to corrosion than because of welding, brazing or other fabricating difficulties. In the electrical industry, it is frequently discarded for those applications requiring, in addition to corrosion resistance, low magnetic permeability. However, many of the fabricating difficulties encountered can be overcome and are being overcome. For example, the spot and seam welding of Type 430 sheets has been helped by the addition of titanium in amounts equal to 5 to 7 times the carbon content.

Machinability, while more difficult than with many of the carbon steels, compares favorably with that of the austenitic steels of the 300 series. In bending, cold heading, drawing and spinning, the behavior of the Type 430 steel is not greatly different from that of the plain low-carbon steels. Soldering and brazing operations can be applied to the Type 430 steel, provided the surfaces are properly cleaned and a suitable flux is used. An exception to this statement, however, can be taken for the 430 alloy modified by additions of titanium; silver brazing has up to now failed to produce an efficient joint for some conditions of service.

In general, many of the objections to the use of the straight chromium steels can be overcome if earnest efforts are made in the way of changes in design and methods of fabrication. These changes should be supplemented by a program of practical corrosion tests. There has been too much of a tendency for designers, lacking definite knowledge of the behavior of the straight chromium steels, to specify alloys of the 300 series, and to look upon the additional cost as a small premium for insurance against failures in service.

W. F. Hodges
General Electric Co.

Successful Fabrication Depends on Correct Technique

Sheffield, England

During the past year great strides have been made in the substitution of straight chromium stainless steels for the chromium-nickel austenitic grades. Although the former had been used for

some trim work, they had never been considered where any deep drawing or welding was involved, and research has proved that with a correct technique they may be both deep-drawn and welded.

The three grades for consideration are the 13% Cr, 17% Cr and 20% Cr steels, all with a carbon content under 0.10%. Of these the 13% Cr has been used for hollow ware and for applications where the corrosive influence is very mild and the metal receives regular washing; the 17% Cr for indoor trim work where regular attention is not given and for outdoor trim work where frequent attention is given, while the 20% Cr will give good resistance to corrosion both indoors and outdoors, even without regular attention.

All these straight chromium steels spin remarkably well and, using a correct technique, will deep-draw well. Owing to the fact that the elongation of a straight chromium stainless steel is only about half that of an austenitic stainless steel, stretching in deep drawing must be avoided, and this is the factor which determines the deep drawing technique, the secret being to avoid stretching and to encourage feeding in of metal by reducing the pressure-plate pressure to a minimum, carefully developing the blank size and lubricating efficiently.

Using these techniques, some particularly interesting pressings have been produced, which include sink bowls and drainers, beer barrel bottoms, tableware (teapots, hot water jugs, tankards, three-partition vegetable dishes), hospital lotion bowls, telephone finger dials, beer trays, saucepans, and housewares.

Welding presented a problem — for the thinner gages this is overcome by development of a high welding speed which reduces to a minimum the grain growth and subsequent embrittlement to which these steels are prone. Some of these steels, in addition to grain growth (which may cause embrittlement), can stiffen due to martensite formation; therefore, a post-welding tempering is advisable. The addition of titanium or columbium to these steels reduces this danger of grain growth, and ductile welds are possible without special welding technique. (It should be remembered that a mirror polish cannot be obtained on these alloys if they contain titanium or columbium, and even a dull polish presents some difficulty.)

We have found in these steels that an area adjacent to the weld is attacked by boiling in a solution of copper sulphate and sulphuric acid in the same way as a nonstabilized 18-8 Cr-Ni steel, and this danger is removed by using a titanium-bearing steel. This phenomenon is not serious for ordinary domestic purposes or for commercial uses where no chemical process is involved.

It will be seen, therefore, that the straight chromium stainless steels are able to take their place in the pattern of our life, and for many of the applications for which they are being used will give a life equal in every way to that of the Cr-Ni austenitic stainless steels previously used.

C. B. Tupholme
Liaison Metallurgist
Samuel Fox & Co., Ltd.

Welding and Brazing

Three Factors Affect Weldability of Chromium-Iron Alloys

Waltham Cross, England

Martensitic stainless steels containing from 11 to 14% chromium and over 0.1% carbon suffer from lack of ductility in the as-welded condition and have a tendency for hardenability cracking (in plate or weld) which may be aggravated by the presence of hydrogen.

Fully ferritic chromium steels containing 16 to 30% chromium suffer from lack of ductility in the as-welded condition due to phenomena associated with the solution of carbides at temperatures above 1200° C. (2190° F.).

All plain chromium steels exhibit notch-brittleness at room temperature and it appears impossible to remedy this defect.

These three factors seriously affect the weldability of the chromium-iron alloys and necessitate the adoption of additional precautions when welding these materials for industrial application. Thus, to improve ductility of welds produced in the chromium-iron alloys, preheating to 400° C. (750° F.) and tempering at 750° C. (1380° F.) after welding is recommended for the martensitic alloys, and preheating to 200° C. (390° F.) followed by tempering at 750° C. after welding is advised for the ferritic alloys. It is usually observed that the ductility of weldments of chromium stainless steels is more satisfactory when using thinner plate material and highly alloyed stainless electrodes of the 25-20 type than when welding thicker material with electrodes of matching composition.

It is our opinion that if substitution of the austenitic steels by the plain chromium steels is unavoidable, weldability will be least impaired by the use of clad material or sheet material up to $\frac{3}{16}$-in. thick for which the effects of shock and stress are less pronounced. In such applications the use of E310 or E310-Cb electrodes of small diameter will be least troublesome; although if it is anticipated that high stresses may arise during welding it may be advantageous to buffer the clad layer, first using E310 electrodes and, to complete the stress-carrying run of weld metal, using a 17-10-Mo type electrode.

From the aspect of corrosion resistance, it is advisable to limit the substitution of high-nickel stainless steels by the chromium-iron alloys to applications involving mildly corrosive media where the use of unstabilized 18-8 steel has proved more than adequate. We believe it is most unlikely that the special grades of high-nickel stainless steel containing such elements as molybdenum, tita-

Composition and Fabrication of Wrought Chromium-Iron Alloys

COMPOSITION *(a)*
(American Iron and Steel Institute Designations; April 1950)

TYPE No.	CARBON	CHROMIUM	NICKEL	OTHER ELEMENTS *(b)*	S.A.E. No. *(c)*
Martensitic (Hardenable)					
501	Over 0.10	4.0- 6.0			51501
502	0.10 max.	4.0- 6.0			
403	0.15 max.	11.5-13.0		Turbine quality; Si 0.50 max.	
406*	0.15 max.	12.0-14.0		Al 3.50-4.50	
410	0.15 max.	11.5-13.5			51410
414	0.15 max.	11.5-13.5	1.25-2.50		51414
416	0.15 max.	12.0-14.0		P or S or Se 0.07 min.; Mn 1.25 max.; Mo or Zr 0.60 max.	51416-F
418*	0.15 max.	12.0-14.0		W 2.50 to 3.50 *(e)*	
420	Over 0.15	12.0-14.0			51420
420-F*	0.30-0.40	12.0-14.0		*(d)*	51420-F
431	0.20 max.	15.0-17.0	1.25-2.50		51431
440-A	0.60-0.75	16.0-18.0		Mo 0.75 max.	51440-A
440-B	0.75-0.95	16.0-18.0		Mo 0.75 max.	51440-B
440-C	0.95-1.20	16.0-18.0		Mo 0.75 max. *(e)*	51440-C
440-F*	0.95-1.20	16.0-18.0		*(f)*	51440-F
443*	0.20 max.	18.0-23.0		Cu 0.90-1.25 *(b)*	
Ferritic (Not Usefully Hardenable)					
405	0.08 max.	11.5-13.5		Al 0.10-0.30	
430	0.12 max.	14.0-18.0			51430
430-F	0.12 max.	14.0-18.0		P or S or Se 0.07 min.; Mn 1.25; Mo or Zr 0.60 max.	51430-F
442*	0.20 max.	18.0-23.0			51442
446	0.35 max.	23.0-27.0		N_2 0.25 max.; Mn 1.50 max.	51446

GENERAL NOTES ON FABRICATION
(Notes based on Metal Progress Data Sheet 84, "The A-B-C of Corrosion and Heat Resisting Steels", copyright 1946 by The Carpenter Steel Co.)

Martensitic (Hardenable)

Hot Working

May be forged, rolled (and in most cases pierced) at 2150 down to 2000° F. (Preheat and soak stock at about 1500° F.) The low carbon and free-machining types should be worked at higher temperatures; high carbon types at lower temperatures. Due to air hardening tendencies, slow cooling may be desirable.

Cold Working

Low carbon varieties in the annealed condition can be easily cold drawn into wire; bars and sheets can be cold rolled, formed, bent, upset, coined and deep drawn. Free-machining and high carbon types are more difficult to work. Alloys work harden about like carbon steels.

Machining

Machine satisfactorily with properly designed tools and lubricants. The free-cutting types (416 and 420-F) contain high sulphur or selenium to give free-machining properties and compare very well with bessemer screw stock B1112. Martensitic alloys are suitable for automatic screw machining.

Welding

Can be welded with gas, electric arc, or by resistance. Preheating and annealing immediately after welding are generally desirable to prevent cracking. Little grain growth. Cracking will be minimized by using austenitic electrodes. Free-machining types not recommended for welding.

Ferritic (Not Usefully Hardenable)

Hot Working

May be forged, rolled and in most cases pierced. To avoid grain growth should be heated quickly and not overheated or soaked. Forge from 2100 down to 1700° F. On last heat, forging may be continued down to 1400° F. to refine grain. Alloys do not air harden.

Cold Working

Can be cold drawn into wire, cold rolled, bent, formed, upset, coined and deep drawn, especially when warm (300 to 500° F.). The alloy with 17% chromium is especially suited for deep drawing and forming. Alloys work harden about like carbon steels.

Machining

Machining rates and tooling practices similar to the above. The free-machining types contain high sulphur or selenium to improve machinability. Are suitable for automatic screw machining.

Welding

Can be welded with gas, electric arc, or by resistance. Anneal to reduce embrittlement alongside of weld. Use small electrodes and low currents to minimize grain growth. Free-machining types are not recommended for welding.

Notes

*This steel not on list of A.I.S.I. standards.

(a) All composition ranges are based on ladle analysis. For standard permissible variations from specified chemical ranges or limits for check analysis, see pages 25 to 31, Section 24, A.I.S.I. Steel Products Manual.

(b) **Manganese:** 1.00 max. in all 400 and 500 types except 416 (1.25 max.), 430-F (1.25 max.) and 446 (1.50 max.). **Silicon:** 1.00 max. in all types except 403 (0.50 max.) and 443 (0.75 max.). **Phosphorus** is 0.040 max. and **sulphur** is 0.030 max. in all types except 416 and 430-F, in each of which they are 0.07% min. if added for improving machinability.

(c) S.A.E. composition limits may be slightly different from the A.I.S.I. analyses quoted.

(d) Same as in 51416-F and 51430-F.

(e) Generally used to resist corrosive attack at temperatures less than 1200° F. Scaling temperature for Type 446 is 1900° F. for continuous service and 2000° F. for intermittent service; other alloys 1500 and 1600° F., respectively, and less.

(f) Same as in 51416-F except that Mn or Zr is 0.75 max.

nium and columbium which have been developed for use in conditions involving highly corrosive media can be satisfactorily replaced by plain chromium.

M. C. T. Bystram
Research Investigator

W. I. Pumphrey
Research Manager
Research Department
Murex Welding Processes, Ltd.

Fabrication Techniques for Type 430 Stainless

Middletown, Ohio

Of the 140 commodities affected by the N.P.A. allocation and control of nickel, many are available today only through the use of Type 430 stainless steel. While the majority of substitutions have involved replacement of nickel-bearing Type 302 with Type 430 chromium stainless steel, plated products affected by these regulations have been engineered to use Type 430 stainless, finished mechanically to high luster.

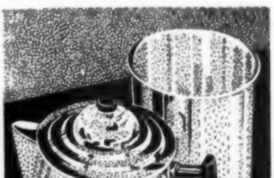
Prior to this regulation and in a free market, the more expensive Type 302 was used in preference to 430, even under conditions where equivalent performance was indicated by service tests. Preference for the nickel-bearing type has been attributed to lower fabricating and finishing costs than possible with Type 430, and total cost per fabricated item almost invariably has been lower with the Type 302 product.

Previous fabricating and service experience with both the 300 and 400 series of stainless steels has influenced the selection of the 400 series steel used for purposes of substitution. The most versatile of the 400 series steels, on the basis of over-all consideration of fabricating properties and corrosion resistance, has been Type 430, and it has been the most frequent selection for replacing the widely used 302 alloy.

In the substitution of Type 430 for 302, modification of drawing operations has usually been necessary. Often, minor redesign of the part to ease sharp radii has been helpful. The more intricate deep drawn items have required more operations and extra anneals have been necessary to restore ductility at critical stages. Type 430 stainless modified with titanium has better ductility than regular Type 430. The modified steel has proved to be more economical to fabricate where marginal performance has been experienced with Type 430. However, parts drawn or formed from either steel and finished to high luster require more cutting operations than Type 302 to develop surface smoothness suitable for buffing.

Welding techniques have been successfully modified to take into account the properties of Type 430 in which welds and heat affected zones are martensitic and brittle. Freedom from brittleness and intergranular corrosion in acid media has been accomplished by proper annealing. Often, however, use of Type 430-Ti has provided a more workable answer to the problem, for with this grade the weld metal and heat affected zones both are free from martensite.

The experience with silver brazed Type 430 joints immersed in water has been that Type 430 corrodes at the junction of the two alloys. Visible rust appeared within a few hours and complete separation occurred after several



days. While modifications in silver brazing technique and alloy are expected to alleviate the corrosion, service tests are recommended for applications involving silver brazed joints in the presence of weak electrolytes.

Hard-temper Type 430 sheet and strip has successfully replaced half-hard Type 301 sheet for conditions requiring good elastic properties. To make this substitution, parts must be of simple design because the fabricating properties of hard-temper Type 430 are poor. Household appliance, commercial dishwasher, and commercial laundry machine components have been made successfully from hard-temper Type 430.

When an increase in section can be tolerated in the design of heat resisting parts made from 300 series stainless steels, use of lower strength Type 430 or 446 is generally possible. Annealing covers for box annealing made from Type 302-B stainless have been replaced with thicker covers of Type 430. This replacement has been successful except in unusually high-temperature operations where distortion has been experienced.

Examples of products successfully converted to Type 430 stainless steel include automotive items, components for domestic household appliances, and hotel and restaurant equipment including back bars, counters and table tops. Architectural components such as panels, trim, kick plates, doors, curtain walls, and roof drainage are expected to perform well, except in coastal regions where outside exposure for Type 430 stainless steel is not recommended.

M. E. Carruthers
Supervising Metallurgist
Research Laboratories
Armco Steel Corp.

Deep Drawing Techniques for Reduced Fabricating Costs

Reading, Pa.

I have probably been the strongest exponent of Types 430 (16% Cr) and 443 (0.20% C, 18 to 23% Cr, 0.90 to 1.25% Cu). It has always been a great personal pleasure to ferret out a job where people are using a two-horse team to pull a one-horse load. Figure 1, p. 104, shows a job using 430 for retainer caps which requires eight operations, this work being done on a 200-9 Waterbury Farrell transfer press. Obviously, no intermediate annealing should be done on this machine set-up. The cap is ½ in. deep and 0.096 in. inside diameter.

Stamping Thin Sheet

Figure 2 shows the successive steps and dimensions for a part made from Type 443. Again we have a multi-operation job done on a Waterbury Farrell transfer press, which means no possible chance of intermediate annealing. The complete story of this job appeared in the June 1950 issue of *Machinery*. Operations started out on a 2¼-in. disk of 0.010-in. steel and wound up in a cup 2.14 in. deep and 0.440 in. outside diameter at top. The work was done by Advance Stamping Co. in Detroit; in fact, both of these jobs were originated by the writer for a manufacturer on the West Coast.

Fig. 1 — A ½-In. Deep Cap Formed Without Intermediate Anneal

Quite a number of similar examples would very definitely show that 75 to 85% of the jobs made from Type 302 can be successfully made from Types 430 and 443 — it is simply a matter of stamping technique. Too often the attempted use of these alloys is abandoned because the operator meets with failure due to the fact that the stamping practice used for other alloys is not suitable for these.

The answer is relatively simple: In drawing the 300 series, anywhere from 45 to 55% reduction is taken on the first cup — a successful practice with the nickel-chromium grades but a mistake when working with the straight chromium steel. It has been my practice never to exceed a 30 or 32% reduction on the first draw.

The other problem which causes so many failures is the lack of attention paid to the design of the punch and draw die. Stretching certainly is a condition to avoid when working with straight chromium steels because of the lower elastic limit inherent in this material. I have found over a period of twenty years that the relationship of the radius on the draw die to the radius on the punch has a very definite bearing on whether the job will be made or not. Probably you can sum up this whole thing simply by saying the Type 400 steels do not progressively harden as do the chromium-nickel series; to work them successfully requires that stretching of the material be held to the barest minimum.

Of course, there is a price differential between the 300 and 400 series. That, however, I consider very minor compared with the many jobs which we have helped to put into production that show significant savings in the fabricating cost. It has been proved a number of times that on certain jobs where Type 302 has required intermediate anneals between draws we can either reduce the number of anneals or eliminate them entirely (if there is only one intermediate anneal) by using straight chromium steels. Thus, on a recent job where formerly Type 302 was used and for which three intermediate anneals were required, we successfully made the job using Type 430 and only one intermediate anneal — and that was done to some rather close dimensions. Before the final operation, which was really nothing more than a restrike die, we annealed to have the part in the softest possible condition and get our close tolerances after the restrike.

When discussing annealing of Type 302 versus 430 or 443, it must also be remembered that the 400 series anneal at about 1350° F. This temperature produces a very slight scale and there is no difficulty removing it. However, the 300 series alloys, such as 302, require temperatures of 1850 to 1900° F.; this means that careful cleaning is needed before the material goes in the furnace, and even with the best condition of cleanliness, a pretty hard scale is produced — one which requires rather severe pickling and often etching of the surface to completely descale — unless you are lucky enough to have a sodium nitride descaling tank.

I have seen conditions such as those just described which have brought as much as a 20¢ per lb. saving on the manufacturing cost. Certainly, savings of this kind are more easily obtainable through intelligent substitution than by leaving the problem in the hands of a purchasing agent whose only approach is to cut all the corners possible so as to buy the material at the lowest possible price. No steel mill can possibly afford to cut prices to this extent.

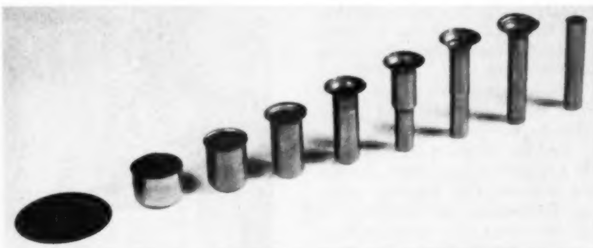


Fig. 2 — Successive Steps in the Production of a Generator Head. Forming was done on a multiple-die transfer press

I definitely believe, and have proved it many times, that the majority of manufacturers are using a two-horse team to pull a one-horse load when they use the Type 300 alloys.

E. Von Hambach

Research & Development Engineer
Carpenter Steel Co.

Aircraft Maker Collecting Data on Service Life

SAN DIEGO, CALIF.

We are beginning to be confronted with the problem of fabricating experimental parts out of the 400 series stainless steels for applications requiring heat and corrosion resistance. These parts, at the present time, are being made from one of the austenitic stainless steels or nickel alloys and in all probability will continue to be made from the same alloys for some time into the future. The experimental parts are being produced to obtain service data pertaining to the ability of Type 400 stainless grades to withstand the rigors of exhaust system or jet component life. For applications such as aircraft exhaust systems, very little factual data can be obtained in less than a year because it takes that long to accumulate 1500 to 2000 hr. of flying time.

Some of the new jet designs incorporate considerable amounts of 400 series steels. On the basis of our experience in the fabrication of these parts and of experimental substitutes for exhaust systems, we have not gained much respect for these substitute steels. Of course, the ability to produce is a matter of becoming accustomed to the various problems, but these steels introduce heat treating and stress relieving requirements in excess of those for the austenitic stainless steels; also, although easy enough to weld, the welding must be accomplished with greater care and at times by the additional operations of preheating and postheating. Drop hammer forming of this stainless requires a complete revamping of techniques and processing to work the metal satisfactorily.

The biggest stumbling block to the use of the 400 series is the lack of information concerning service life. It is true that most of us in the aircraft industry have had one or more parts fabricated from Type 400 stainless steel that have given excellent results, but that is hardly any assurance that any given part should be changed overnight from an austenitic stainless steel to one of the straight chromium types without extensive and thorough service testing. For this reason any substitution for the 300 series, insofar as existing designs are concerned, probably will be long and involved. We are all willing to try the straight chromium types, but on a production basis it is likely to be a long up-hill pull before any general trend in this direction will be noticeable.

W. G. HUBBELL
Chief Metallurgist
Ryan Aeronautical Co.

Aircraft Industry Takes a Cautious Attitude

Few Substitutions of Type 400 for Type 300 Series in Airframes

HAWTHORNE, CALIF.

It has been pointed out that the 17% chromium steel (Type 430) is used extensively for such applications as door handles and automobile trim and that they are very corrosion resistant. However, it must be noted that this application has extremely low or insignificant stress characteristics. The uses of 400 series alloys in precision castings for latch mechanisms and in bar stock for engine support fittings are common applications founded on mechanical properties and corrosion and heat resistance not available in 300 series steels.

The preponderance of stainless steel used in aircraft is sheet applications. Whereas the columbium and titanium stabilized products serve excellently at elevated temperature, it is doubtful if products of the 400 series could be expected to withstand any necessary high stresses above 600° F.

The homogeneity of chemical constituents in the 300 series steels is essentially of a high order and rejections due to discontinuities are infrequent; it has been our experience that the segregation of chromium in the straight chromium stainless grades has accounted for considerable controversy insofar as magnaflux and other inspection procedures are concerned.

The attainment of optimum mechanical properties in the 400 series steels is often by way of heat treatment — frequently very difficult to control due to the extremely critical chemical balance in the analyses. For example, it has been observed that Type 431 responds very differently to a given heat treatment when the chemistry within the specification chemical limits varies appreciably.

In general, it is believed that insofar as airframe applications are concerned, very few substitutions can be made of Type 400 series for Type 300 series.

KEITH F. FINLAY
Research Engineer
Northrop Aircraft, Inc.

Special 410 Preferred for Pressure Equipment In Aircraft

BUFFALO, N. Y.

Many of the large metal working industries now are looking at the 400 series stainless steels as *second-choice* materials. In current designs, Bell Aircraft Corp. has met performance demands by specifying these steels as *first-choice* material.

Specifically, the problem was this: It was necessary to manufacture large pressure vessels which were required not only to operate at high pressures, but also to have excellent corrosion resistance. Weight, as in any aircraft product, was an important factor. Therefore, our engineers specified that the material must have a minimum tensile strength of 180,000 psi.

Selected heats of Type 410

High-Pressure Tanks

stainless met these requirements admirably, and over the past few years a great many cylindrical tanks and tanks made of coiled tubing have been manufactured from this steel. We say "selected" because it was found that Type 410, melted to the commercial chemical composition limits, sometimes would not respond adequately to heat treatment. This was due to large quantities of ferrite which were retained in the structure at the austenitizing temperature. A procurement specification was written requiring that carbon be held on the high side (0.10 to 0.15%) of the commercial range, and chromium on the low side (11.50 to 12.50%). With these selected, restricted-chemistry commercial heats, a fully martensitic structure is obtained using only an air quench.

All types of fabrication operations are performed in the manufacture of these tanks, including resistance seam welding and gas-shielded-arc fusion welding. A preheating temperature of 350 to 500° F. is used in the fusion welding operation. The excellent air-hardening characteristics of this type of steel are indispensable because air seems to be the only satisfactory quenching medium for large tanks.

Bell is satisfied that, for these applications, the 400 series steels are first-choice materials and not substitutes dictated by current shortages.

A. E. LEACH
Metallurgical Engineer
G. F. KAPPELT
Chief Metallurgist
Bell Aircraft Corp.

Prefer the 400 Series Alloys for High-Strength Uses

DALLAS, TEX.

We have used the 400 series alloys in the fabrication of our products not as a direct substitute for the 18-8 types, but rather for their corrosion and heat resistant characteristics at the high-strength level of 175,000 psi. (ultimate tensile strength). Specifically, the steels used were bar and rod forms of Types 403, 410, 418,* and 431. With the exception of Type 431, all exhibited an uncertainty in reaction to heat treatment on account of the normal variations in chemical analysis that take place from heat to heat. It was determined that it is necessary to have similar analyses for all heats so as to get similar heat treating characteristics and thus avoid retempering operations on each heat of material.

The control of carbon is most essential. This is best illustrated in Types 410 and 403: Type 403 is similar to 410 but is known as the turbine quality grade of the 12% chromium steels. It is made within the composition limits of Type 410 but carbon and silicon are restricted to give uniform hardening during heat treatment.

Type 418 steel is similar to 403, 410 and 416 but has the addition of tungsten. It has a higher creep strength and resistance to high-temperature effects than any of the other grades. Should one desire to use this alloy at a high-strength level, it would be necessary to specify close tolerances in chemical analysis to assure uniform heat treating procedures.

Type 431 is the alloy used by this company with the most success. Although from the aspect of chromium conservation this alloy might not be the most desirable because it has a 2% nickel content, it does have the most satisfactory reaction to heat treatment of all the types mentioned; from our point of view, it has proved most desirable.

Aside from the disadvantages of the inconsistency of reaction to heat treatment, the chromium stainless alloys have other idiosyncrasies which might be well to remember. They are as follows:

1. Temperatures from 800 to 1100° F. should be avoided with all these alloys due to loss of impact and corrosion resistance.

2. Bolts made of straight chromium stainless must be fastened with nuts of 18-8 to prevent the seizing or galling which would result from using like material.

3. Procurement of these alloys at the present time is a problem in that they are not normally stored by most warehouses and must be purchased from the mill.

4. These chromium-iron alloys will discolor and therefore, where appearance is a factor, they should be plated.

As has been mentioned, we do not use these alloys as a direct replacement for the 18-8 stainless steels but rather for their specific high-strength characteristics. Companies that must replace the 18-8 type with the 400 series alloys will probably not be confronted with most of the problems mentioned.

S. F. HELD
Supervisor
Metallic Materials
Chance Vought Aircraft Division
United Aircraft Corp.

*Type 418 (nonstandard) is low-carbon 416 with a tungsten addition.

Preliminary Investigation Offers Promise

LOS ANGELES

A preliminary investigation to determine if it would be feasible to consider A.I.S.I. Type 430 as a substitute for A.I.S.I. Type 302 (annealed) sheet products has shown enough promise to do some further work for which we have just ordered material. Formability and mechanical properties are comparable to those of annealed Type 302. We have not yet investigated the weldability of Type 430.

R. R. JANSSEN
Material and Process Engineer
North American Aviation, Inc.

Poor Corrosion Resistance to Salt a Serious Drawback

WASHINGTON, D. C.

United States naval aircraft, by the very nature of their primary mission, are subject to salt-laden atmospheres. Because of this, the use of straight chromium steels has been limited. The resistance of the chromium grades of corrosion resisting steels to attack by this atmosphere, when compared to the chromium-nickel grades, has generally been poor.

However, in a number of aircraft turbines, Type 403 is used as the material for compressor vanes and disks. In this application, the material, although selected primarily for its excellent damping characteristics, is also subjected to heat (from ambient temperatures to about 500° F., depending on engine type and the location of the part within the engine), fatigue stresses and salt atmosphere. Except for the latter requirement, Type 403 is eminently satisfactory.

Figure 3 illustrates severe attack in the compressor section of a carrier-based jet plane. While the average amount of corrosion is less intensive than that illustrated, the problem nevertheless is with us and must be resolved. Various types of coatings and plating (including a light flash of chromium) are being tested but results are thus far inconclusive.

(LCdr.) E. J. Wheelahan, U.S.N.
Metallurgical Engineer
Navy Bureau of Aeronautics

Polish and Plate to Prevent Development of Rust

Seattle, Wash.

Type 400 stainless steels have been used in the airframe industry rather sparingly. We have used A.I.S.I. Types 410 and 420 heat treated and drawn in the range of 600° F. Originally we specified a tensile range of 180,000 to 220,000 psi. for the 410 grade when quenched in oil from 1800° F. and drawn at 600° F. We have learned that this was somewhat higher than can be obtained if the carbon content is on the low side and the chromium content is on the high side of the specification. We are now specifying a tensile range of 160,000 to 200,000 psi. when drawn at 600° F. We have used it in the tensile range of 110,000 to 140,000 psi. when drawn at 1150° F.

Precision castings of the Type 410 analysis have given us some trouble from a consistency standpoint. We have found some very hard parts within a heat treated lot, some being near 230,000 psi., while other parts in the same group checked at 190,000 psi. To have satisfactory appearance after exposure to weather, the castings have to be plated or buffed to a high polish. The Type 420 is specified with a tensile range of 240,000 to 280,000 psi. when drawn at a temperature of 600° F.

Some corrosion tests have been run on these 12% chromium alloys and we find they require a very good polish to keep from developing rust pits on the surface. As-cast surfaces, sandblasted surfaces or rough machined surfaces rust quite rapidly when exposed to wet weather; when used in these surface conditions, we require that the metal be plated. It shows best resistance to corrosion when heat treated.

Type 431 is being used for corrosion and heat resistant bolts. It contains 17% Cr and 2% Ni which improves corrosion resistance considerably. The bolts are heat treated to a minimum tensile strength of 115,000 psi.

Type 440 stainless has been used for pump parts, bearings and bearing races. We are, at present, considering making welded tanks from 410 or 431 sheet material. The tank will be heat treated to a tensile strength of 180,000 to 200,000 psi. Air hardening properties of this analysis are interesting when considering heat treatment of large bulky parts.

J. W. Sweet
Chief Metallurgist
Boeing Airplane Co.
Seattle Division

Fig. 3 — Corrosion on Blades in Compressor End of Jet Engine

High Corrosion Resistance of Chromized Coatings

Cambridge, England

One difficulty in the replacement of 18-8 class steels with straight chromium irons or steels is that, for equal or nearly equal corrosion resistance, a considerably higher chromium content is needed. Even Type 446 (23 to 27% Cr, 0.35% max. C) is by no means always successful, and irons or steels of still higher chromium content, which are expensive in chromium, have doubtful

Heat Treating Temperatures for Wrought Chromium-Iron Alloys

Type	Forging*		Annealing		Hardening	Tempering‡	Welding	
	Start (Max.)	Finish	Full	Process†			Preheat	Postheat
Martensitic Alloys (Hardenable)§								
403	2150° F.	1550° F.	Slow Cool from 1500 to 1650° F.	1200 to 1400° F.	Oil Quench from 1700 to 1800° F.; Air Cool from 1800 to 1850° F.	400 to 1400° F. *(a)*	300 to 400° F. *(b)*	Anneal 4 hr. at 1250 to 1350° F. per inch of thickness
410	2150° F.	1550° F.	Slow Cool from 1500 to 1650° F.	1200 to 1400° F.	Fast Cool from 1700 to 1850° F.	400 to 1400° F. *(a)*	300 to 400° F. *(b)*	Same as 403
414	2150° F.	1500° F.	Not Practical	1200 to 1300° F.	Fast Cool from 1800 to 1900° F.	400 to 1300° F.	300 to 400° F. *(b)*	Same as 403
416	2200° F.	1550° F.	Slow Cool from 1500 to 1650° F.	1200 to 1400° F.	Fast Cool from 1700 to 1850° F.	400 to 1400° F. *(a)*	300 to 400° F. *(b)*	Same as 403
420	2100° F.	1750° F.	Slow Cool from 1550 to 1650° F.	1350 to 1450° F.	Fast Cool from 1800 to 1900° F.	300 to 900° F.	300 to 400° F. *(b)*	Same as 403
431	2100° F.	1500° F.	Not Practical	1150 to 1225° F.	Fast Cool from 1800 to 1950° F.	400 to 1200° F.	300 to 400° F. *(b)*	Same as 403
440-A	2100° F.	1750° F.	Slow Cool from 1600 to 1700° F.	1350 to 1450° F.	Fast Cool from 1850 to 1950° F.	300 to 800° F. *(c)*	300 to 400° F. *(b)*	Anneal 4 hr. at 1400 to 1450° F. per inch of thickness, furnace cool
440-B	2100° F.	1600° F. *(d)*	Slow Cool from 1550 to 1650° F. *(e)*	1350 to 1450° F.	Fast Cool from 1850 to 1950° F.	300 to 800° F. *(c)*	300 to 400° F. *(b)*	Same as 440-A
440-C	2100° F.	1600° F. *(d)*	Slow Cool from 1550 to 1650° F. *(e)*	1350 to 1450° F.	Fast Cool from 1850 to 1950° F.	300 to 800° F. *(c)*	300 to 400° F. *(b)*	Same as 440-A
Ferritic Alloys (Not Usefully Hardenable)								
405	2100° F.	1400° F.	Air Cool from 1350 to 1500° F.	Same as full			300 to 500° F.	Anneal at 1400 to 1500° F., cool 50 to 100° F. per hr.
430 *(f)*	2000° F.	1350° F.	Air Cool from 1400 to 1500° F.	Same as full *(g)*			300 to 500° F.	Same as 405
430-F	2100° F.	1350° F.	Air Cool from 1400 to 1500° F.	1250 to 1400° F.			300 to 500° F.	Same as 405
442	2100° F.	1500° F.	Air Cool from 1450 to 1600° F.	....			300 to 500° F.	Same as 405
446	2050° F.	1500° F.	Air Cool from 1500 to 1600° F.	Same as full			500° F.	Long soak at 1600° F., air cool

REFERENCES

Data compiled from *Steel Products Manual, Section 24*, A.I.S.I.; *The Book of Stainless Steels*; *Metals Handbook, 1948 Edition*; *Republic Enduro Stainless Steels*; Allegheny Ludlum's *Stainless Steel Handbook*; Linde's *The Oxy-Acetylene Handbook*; Lincoln Electric's *Procedure Handbook of Arc Welding Design and Practice*.

*Work should be heated slowly to 1500° F. for martensitic alloys and to 1400° F. for ferritic alloys, allowed to soak thoroughly and then brought to temperature fairly rapidly; ferritic alloys must not be soaked at high temperatures and higher-carbon grades of the latter must not be overheated. Finishing temperatures for ferritic steels are around 1500° F., martensitic alloys around 1700° F. followed by retarded cooling.

†To improve machinability or as an intermediate anneal between stages of cold working.

‡Parts subject to impact should not be tempered above 700° F. [See footnotes *(a)* and *(c)*.]

§Will harden in air when cooled from above 1500° F., can be quenched in air or oil, depending on thickness of section.

(a) 400 to 850° F. for high tensile strength (750 to 1050° F. gives low impact and corrosion resistance), 1100 to 1400° F. for low tensile, high impact, good corrosion resistance.

(b) British practice is to preheat to 750° F. (see comment, p. 101).

(c) Quench after draw to avoid temper brittleness.

(d) Forgings should be slowly cooled (as in ashes) from 1600° F.

(e) Morton (The Book of Stainless Steels) recommends slow heat to 1600° F., cool in furnace to 1000° F., reheat to 1425° F., hold 24 to 36 hr., and cool slowly in furnace.

(f) Has rather wide range of chemical analysis (0.12 max. C, 14.0 to 18.0% Cr). With carbon on high side and chromium on low side the alloy is hardenable, much like Type 416; with carbon on low side and chromium on high side the alloy is ferritic, that is, not usefully hardenable by heat treatment.

(g) "Cold" work should be done after heating to 250 to 400° F.

mechanical properties due to the possible formation of sigma constituent during some conditions of heat treatment.

A way in which the favorable corrosion resistance of iron highly alloyed with chromium can be utilized without the disadvantages just mentioned lies in the use of chromized mild steel—that is, mild steel that has been heat treated in atmospheres containing volatile chromium compounds, or in salt baths containing dissolved chromium compounds, so as to produce an alloyed surface layer. The chromium content on the outside of the chromized layer may reach 40% or more, and the mean chromium content of the layer is around 20%. Consequently, for many applications chromized mild steel parts can have a better corrosion and oxidation resistance than the best available straight chromium irons, and can replace 18-8 class steels with little or no loss of efficiency.

The earliest chromizing processes utilized chromous chloride as the volatile chromizing reagent; this was either generated from metallic chromium and hydrogen chloride gas, or from solid chromous chloride carried on porous refractory material, and was usually carried in hydrogen. Under such circumstances, both interchange and reduction reactions (T. P. Hoar and E. A. G. Croom, *Journal* of the Iron and Steel Institute, Vol. 169, 1951) occur on iron or mild steel surfaces exposed to the chromizing vapor between 1830 and 2000° F.,

$$CrCl_2 + Fe \rightarrow Cr + FeCl_2$$
$$CrCl_2 + H_2 \rightarrow Cr + 2\,HCl$$

and interdiffusion of chromium and iron leads to the type of alloy layer described.

Early chromized coatings suffered from several disadvantages, notably a tendency to porosity. While for heat resistant purposes such porosity is of no great account, for corrosion resisting purposes it can be very serious. Several newer processes have recently been described; in one, a salt bath* rather than a carrier gas is used to contain the chromizing reagent; in another, chromous fluoride† is used rather than chloride; and in a third, chromous iodide‡ is the active reagent. This last process is of particular interest; operating as it does as a "pack" process, with little loss of iodine, it is not as expensive as might at first thought appear. The reagent gas also contains ammonia, which cracks on the steel surface and decarburizes it to some extent, removing another difficulty in the formation of chromium-iron alloy coatings on a carbon steel.

Chromized parts made by the last process are in use in Great Britain in agricultural machinery; food-processing and chemical equipment; photographic apparatus; washing machines and the like—where otherwise 18-8 steel parts would have to be used for corrosion resistance. Heat resistance uses include parts for gas and kerosene stoves (chromized sheet is an approved specification for the latter).

A matter still outstanding in the production and use of chromized steel—or, as it might more accurately be designated, chromium-iron-surfaced steel—is the provision of high mechanical qualities of the basis metal after the chromizing treatment. Since the chromizing process must take place at the rather high temperature of 1830 to 2000° F., distortion and structural changes are liable to occur with straight mild steels, and for some applications the mechanical properties of the treated material will be insufficient. There is no doubt, however, that just as special stock is used where carburizing or nitriding is to be carried out, special chromizing stock will become available in the future.

T. P. Hoar
Department of Metallurgy
University of Cambridge

420 and 431 in British Engines

Used for Compressor Blades

Coventry, England

We have used chromium-irons corresponding approximately to Types 403, 420 and 431 for a considerable number of years. They have been used for components where good resistance to corrosion or scaling was required but where stresses were low, or high temperatures were not encountered. These were *not* chosen as substitutes for the 18-8 types but solely on their own intrinsic merits.

Types 420 and 431 equivalents have been used extensively for compressor blades and the primary reason for this choice is that higher tensile properties can be obtained than in the 18-8 alloys. Our preference is for Types 403 and 420 for all purposes, the use of Type 431 (2% Ni) being gradually discontinued owing to its tendency toward low cross-grain properties.

Our only experience with these three alloys is confined to bar or forgings, but we have made some laboratory tests on a high-chromium stainless iron sheet. We have no immediate use for this material, because our general practice is to use mild steel or low alloy sheets, except where conditions of temperature and stress make the use of another analysis advisable, and in such situations we go directly to the 18-8 types.

As we are not concerned with finish from an ornamental point of view and we do not as a rule have any difficulty in producing adequate corrosion protection of nonstainless alloy components, there is no reason for us to use plain chromium steels instead of nonstainless alloys.

We only rarely weld any of these, but when we do, postheat treatment is always used. Wherever possible, mechanical fabrication methods are utilized and the general rule is to treat the materials as nonweldable.

C. A. Dalton
Chief Metallurgist
Armstrong Siddeley Motors, Ltd.

*I. E. Campbell, V. D. Barth, R. F. Hoeckelman and B. W. Gonser, *Transactions* of the Electrochemical Society, Vol. 96, 1949, p. 262.

†P. Galmische, Res. Aeronaut., No. 14, 1950, p. 55.

‡R. L. Samuel and N. A. Lockington, *Metal Treatment*, Vol. 18, 1951, p. 354.

Some Rules for Using Tubular Products of the 400 Series

BEAVER FALLS, PA.

Type 430 is likely to be the most widely used substitution for 18-8 in tubular products and will serve admirably for ornamental use, for various requirements in the chemical field (especially relating to nitric acid production and nitration work), and may be used in certain heat exchange equipment. In welding this grade and the higher chromium Type 446, grain growth is likely to occur and although stress relief treatments between 1300 and 1500° F. will improve ductility, these metals are likely to be impact-sensitive and subject to notch failure. Both are subject to the well-known 885° F. embrittlement and use is generally avoided between 700 to about 1000° F. because of the fragility of these materials after exposure within that temperature range. Type 446 is also subject to sigma phase precipitation between 1000 to about 1300° F., and may also become severely embrittled in this range. Both alloys exhibit a loss in corrosion resistance in certain media, especially after 885° F. embrittlement, and the higher chromium alloy suffers to some extent if sigma phase is present.

In general, the rules for use should be to avoid service temperatures of 700 to 1000° F. on Type 430, and 700 to 1350° F. on Type 446. At higher temperatures, Type 446 will serve admirably as a heat resisting material and can be used for air heaters or recuperators and it serves very well for stationary soot blower tubes in boilers where it has been a commonly used material for such service.

Type 410 is a useful steel for a wide variety of heat exchange equipment, particularly in oil refining, and it is not subject to embrittlement; it can be used successfully at various temperatures up to its scaling point of about 1250° F. It is resistant to high-sulphur oils and has been used in a number of installations in oil refinery heater tubes, especially in those circumstances where the pressures are moderate so that the stresses imposed on the tubing can be adjusted to conform with the high-temperature properties of this material. Type 410 is useful also in mechanical tubing which can be hardened and tempered for oil field equipment, valve parts and many other items. Composition can be adjusted, within usual specification limits, so that good hardenability can be secured (on simple air normalizing and tempering treatments) with mechanical properties considerably above those of the annealed condition. Tubes of Type 405 are available and are commonly used where nonhardening characteristics are desirable for welded constructions.

The production of welded tubes from Type 410 is somewhat fussy, due to the air hardening nature of the alloy, but it is being successfully welded in light gages by observing certain precautions of preheating and stress relieving so as to avoid weld cracking. Where higher mechanical properties in the heat treated form are required than are available in Type 410, these can be obtained by using Type 414.

Likewise, Type 443 (20% Cr, 1.0% Ni) can be employed where the corrosion resistance of Type 430 is not quite adequate. The comments given above with respect to aging embrittlement and sigma phase are applicable to Type 443 alloy, which is also subject to 885° F. embrittlement and to some sigma phase precipitation between 1000 and 1200° F.

More detailed information concerning the properties of these straight chromium steels has previously been supplied by the undersigned in *Metal Progress* articles entitled "Properties and Characteristics of 27% Chromium Iron" for May 1946 and in "High Chromium Irons" for April 1947.

H. D. NEWELL
Chief Metallurgist
Tubular Products Division
The Babcock & Wilcox Co.

Welded and Seamless Tubing —Properties and Applications

Type 430 Welded Tubing, Stabilized With Titanium

CLEVELAND

Biggest problem in connection with welding Type 430 tubing has been inspection for weld quality. The weld in the as-welded condition is extremely brittle and fails on any of the standard tests which are applied to tubing, such as the flattening or crushing test and the cone or plug expansion test. Subsequent heat treatment at about 1450° F. generally removes or alleviates this brittle condition and the tube can be manipulated without weld failure.

Several years ago an investigation was made to determine the influence of a stabilizing element such as columbium or titanium on the weldability of this grade. Extensive substitution of Type 430 for Type 304 became a necessity at about the same time that columbium was placed on the restricted list, consequently most of the work has been confined to the titanium-treated 430. It was found that with carbon on the low side, chromium on the high side and with the addition of approximately 0.50% titanium, the tube in the as-welded condition can be flattened on itself (with the weld positioned at 90° from the applied load) with little or no fracture. Therefore, the stabilized grade is preferred for its superior weldability.

Type 430 with titanium is definitely recommended if any assembly welding is to be done on the tube, and is also more desirable for severe fabrication because it has somewhat better ductility than the old Type 430, unstabilized. It should be distinctly understood that the 430-Ti analysis does not approach the chromium-nickel grades for ductility

and corrosion resistance, and there is no inference that the addition of titanium eliminates all problems in connection with the use of Type 430. Any applications or substitutions of 430 (either with or without titanium) for 304 should be thoroughly investigated before a decision is reached on its acceptability.

V. W. WHITMER
Ass't. Chief Metallurgist
Central Alloy District

J. S. ADELSON
Chief Metallurgist
Steel and Tubes Division
Republic Steel Corp.

High-Temperature Properties of Ferritic Stainless Tubing

PITTSBURGH

One of the grades of ferritic stainless steel most widely used in the manufacture of tubing is A.I.S.I. 405 (12% Cr + Al); there is also some demand for other grades of the 400 series. However, the most commonly used stainless tubing is of the austenitic type or 300 series.

In the production of stainless steel tubing by the cold drawing or tube reducing methods, the ferritic grades, in general, are more difficult to handle than the austenitic. When experience has been acquired with the hot extrusion method, it is quite possible that the practice obtained with certain ferritic and austenitic grades will be improved. Furthermore, it may be possible to produce by the hot extrusion method some grades of stainless steel tubing not yet available.

In the 400 series the Type 405, due to its aluminum content, is often welded without preheat or postheat. The presence of aluminum in the proper amount prevents excessive hardening in the heat affected zone of the weld, but a large amount of aluminum leads to grain coarsening in this region. In addition, the 12% Cr steels with carbon below 0.15% may be less susceptible to embrittlement than the higher chromium steels. Impact properties at ambient temperature of Charpy keyhole-notch specimens from several heats of chromium steels before and after 10,000 hr. exposure at 900 to 1200° F. are reported in Table II.

Extensive investigations using the Charpy impact have shown that the transition temperature of Type 410 and 410-Mo steels was not adversely affected by exposure at 900 to 1200° F., but the transition temperature of the 430 steel was raised. The Type 410 with not over 0.15% carbon also appears to be more stable after exposure at 900 to 1200° F. for 10,000 hr. with respect to microstructure and tensile properties.

Sigma was observed after 10,000 hr. exposure at 1050 and 1200° F. in Type 446. After a 34,000-hr. treatment at 1200° F., sigma was also observed in Type 410, 410-Mo and 430 steels.

There has been some increase in demand for the high-carbon hardenable grades of Cr steels. These grades, however, are not generally used for high-temperature service. For such service the low-carbon (0.15% max.) grades are usually employed. The creep-rupture properties of the 400 series are inferior to the austenitic grades, which has limited their use. Some creep-rupture properties obtained before and after 10,000 hr. exposure at 900 to 1200° F. are given in Table III.

A. B. WILDER
Chief Metallurgist
National Tube Division
U. S. Steel Co.

Table II — Impact Values of Ferritic Stainless After Heating

A.I.S.I. Type	Before Exposure Ft-Lb.	Exposed 10,000 Hr. 900° F. Ft-Lb.	1050° F. Ft-Lb.	1200° F. Ft-Lb.
410	33	39	—	21
416	42	26	27	36
405	35	—	39	34
410-Mo	45	56	56	54
430	46	1	3	4
446	1	½	½	½

Table III — Creep-Rupture Properties*

A.I.S.I. Type	Before Exposure 900° F.	1050° F.	1200° F.	After 10,000 Hr. Exposure 900° F.	1050° F.	1200° F.
410	24.0	11.7	4.9	24.0	12.0	4.8
405	25.0	9.2	3.8	—	9.0	3.6
430	30.0	12.0	5.0	40.0	14.5	5.0
304	49.0	27.0	14.0	55.0	29.5	17.2

*Stress in 1000 psi. for rupture in 1000 hr.

Applications for Straight Chromium Stainless Tubing

UNION, N. J.

The amount of straight chromium stainless tube that has been made for replacement of austenitic grades has been, in the main, for mechanical applications. It has also been for applications involving minor corrosion. To illustrate, the hospital equipment trade, chair manufacturers and other uses of a strictly mechanical nature involving atmospheric corrosion principally, were changed over to straight chromium as a result of conservation moves on the part of N. P. A. Contrasted to mechanical applications, of course, are pressure piping applications, and it seems that most of the people who need tube for pressure work were able to justify, either from a corrosion standpoint or some other, the necessary nickel-bearing materials so that they never had to resort to substitutions.

However, the use of nickel-free or low-nickel stainlesses in the manufacture of welded tubing has not been too extensive. I believe that this is a result of having an industry that is 100% controlled by Washington regulations so that materials of a low priority rating, or no rating, receive no manufacturing time in the industry. Nevertheless, as a company within the industry we anticipated a great increase in this type of merchandise and circulated among the consumers the following information.

Because the chromium ferritic steels contain chromium in almost the same percentage as the austenitic grades which they re-

Substitutions Suggested

place, the use of these steels would not occasion any increased drain on the chromium supply. Until such time as chromium becomes as critical as nickel, we suggest the following alternates for consideration:

Present Uses	Consider Using
Ornamental, 304	430
304, 347, 321	443
316, 309, 310	329*

*0.10-0.20 C, 0.03 max. S and P, 1.0 max. Mn, 0.75 max. Si, 26.5-28.0 Cr, 3.0-5.0 Ni, 1.0-2.0 Mo.

It is not expected that these substitutions will be entirely satisfactory in every instance, but they will cover many uses.

Type 430 is entirely adequate for many of the corrosion problems where other alloys have been usually selected (due to availability and ease of fabrication). We have never availed ourselves completely of the inherent advantages which this alloy offers corrosion-wise, due to some slight fabricating disadvantages. However, new techniques and methods of welding have overcome this difficulty.

In many places where Type 430 is not sufficiently corrosion resistant, Type 443 may have sufficient additional corrosion resistance, due to its higher chromium content and its copper addition, to be used satisfactorily. The added chromium content of this type gives it superior corrosion resistance to Type 430 in oxidizing conditions. It resists molten nonferrous metals, such as copper and brass, has relatively high corrosion resistance for mixed nitric-sulphuric acids, and excellent resistance to nitric acid.

All these ferritic steels have a strong tendency to become embrittled in the weld area unless annealed after welding. They can be welded with gas, electric arc or any of the shielded arc methods. It is best to use small electrodes and low currents to minimize the grain growth. They can be fabricated by cold working, since the rate of hardening during cold work is lower than that of the austenitic steels (about the same as carbon steels).

Type 430 particularly is good for spinning, deep drawing and any other type of severe deformation. These alloys should bend and fabricate as readily as the alloys they replace. Until more information is gathered from their use, it would be best to keep welds on neutral axis in making close radius bends. Polishing, machining, and cutting should not be any more difficult.

Type 329, due to its greater hardness, requires a little more power to roll into tube sheets and would likely require slightly more power to bend. However, work hardening, due to cold work, is less than in the comparable austenitic types.

The following products, formerly made of austenitic steels, could be made readily of one of these substitutes.

Type Used	Application	Suggested Substitute
304	Filler tube	430
304	Door frames	430
302	Outdoor furniture	430
304	Soda fountain pumps	430
302	Textile spindle racks	430
302	Photographic printer support	430
304	Rectangular lift on filler machine	430
316	Fatty acid heat exchanger	329
304	Paraffin melter	430
347	Pilot light tube	443
304	Sulphate evaporator	430
304	Coils—synthetic rubber manufacture	443
304	Heater for pulp liquors	443
316	Tube in tube heaters	329

In the corrosion field, Type 430 has been used successfully in the black liquor evaporators in the sulphate pulp mills. This shows quite a diverse range of applications and causes us to believe the alloy has greater possibilities than have previously been acknowledged.

During the second World War, Type 443 (20% Cr, 1% Ni) was used to resist many mixed acids and seems to be able to replace 304 in many applications. In the textile field it can often substitute for tubes of 304.

Type 329 will have a place for most applications where 316 was formerly used — in the chemical, sulphite paper, rayon, synthetic rubber and food processing industries. It will help cut down considerably on the amount of nickel purchased for such uses and thereby stretch the nickel over a greater number of feet of tube than if normal austenitic types are used.

A. S. T. M. Specification No. A-268 covers tubing in these high-alloy analyses for general services. There is no corresponding A.S.T.M. specification for pipe.

J. A. Deitrich
Manager
Alloy Tube Division
Carpenter Steel Co.

Chromium-Iron Castings

Substitution of 18-8 Types With Straight Chromium Alloys for Castings

Detroit

Straight chromium alloys have not generally been regarded to be as satisfactory for casting purposes as the nickel-chromium alloys of the 18-8 types. The Alloy Casting Institute recognizes four types of straight chromium alloys as follows:

A.C.I. Grade	Chromium %	Corresponding A.I.S.I. Type
CA 15	12	Type 410
CA 40	12	Type 420
CB 30	20	Type 431
CC 50	28	Type 446

The CA 15 alloy is probably the most popular grade of cast straight chromium alloy; however its resistance to corrosion as measured by the boiling 65% nitric acid test would generally not be sufficiently good to be used as a substitute for 18-8 where the latter is actually required.

The CB 30 (20% Cr) alloy, while showing better corrosion resistance than the CA 15, is still slightly inferior to 18-8, but may be acceptable as a substitute where conditions are not severe. The mechanical properties of the low-carbon grade (0.10% max.) are inferior to 18-8 but again may be acceptable as a substitute where these requirements are not

too severe, especially with respect to impact. Increasing the carbon to approximately 0.18%, while improving the ductility of the alloy after tempering heat treatments, further reduces the corrosion resistance.

The 28% chromium alloy (CC 50) in general shows adequate corrosion resistance (boiling 65% HNO_3 test) and from this standpoint would appear to be better adapted as a substitute for 18-8. In order to develop acceptable mechanical properties in the 28% chromium alloy, it appears necessary to use nitrogen modifications or employ moderate amounts of nickel in the order of 3 to 5% to refine the inherently coarse grain structure which the high-chromium alloys possess in the cast condition.

Most alloy foundries have had sufficient experience with the high-chromium alloys to manufacture the castings successfully.

R. J. WILCOX
Technical Director
Michigan Steel Casting Co.

2% Ni Is Good for High Chromium-Iron Alloys

SCOTTSDALE, PA.

We have probably had a little more experience with the straight chromium alloys than some of our worthy competitors in that the original "Duraloy", known years ago as "Duraloy A", was 27% Cr, minimum Ni, and the "Duraloy B" was 16 to 18% Cr, and those two alloys constituted the bulk of our tonnage — or should I say poundage? for in those days there was no considerable tonnage of these being produced.

We believe that Type 446 (25% Cr) plus probably 3% Ni and 1% Mo would satisfactorily replace the 18-8 Cr-Ni in its resistance to pickling acids and many related products. The 16% Cr with about 2% Ni (Type 431) has very good corrosion resistance in many acids and has shown very good results in the salt spray test. In addition to this, excellent physical properties can be obtained from it in the air-quenched and drawn condition. Representative physical properties for this alloy in the air quenched and drawn condition are as follows:

Tensile strength	160,000 psi.
Yield point	125,000 psi.
Elongation in 2 in.	14%
Reduction of area	42%

In the heat resisting field, however, Type 431 has its limitations at around 1300° F. (intermittent operation) because of grain growth which usually results in cracks. The Type 446 (straight 25% Cr) in heat applications has, of course, excellent oxidation resistance but is lacking in strength. Consequently, in any substitution of 446 for nickel-chromium it would probably be necessary to revise the design of the part to offset the difference in strength.

HARVEY T. HARRISON
Vice-President
The Duraloy Co.

The Chemical Industry Can Extend Applications

Chemical Industry's Experience Is Reasonably Satisfactory

WILMINGTON, DEL.

The restriction on the use of nickel and the more common nickel-bearing stainless alloys has resulted in the use of the low-nickel and straight chromium type stainless alloys for a number of applications in the chemical industry where 18-8 types were previously used, or would have been used more or less arbitrarily if they had been available. Fortunately, the restrictions involved were anticipated in most instances to the extent that test programs could be set up to check at least partially the usefulness or suitability of the proposed alternate stainless alloys and decision reached as to whether the use was likely to be satisfactory or different types of construction should be employed. In general, where the low-nickel and straight chromium stainless alloys have been used as alternates, experience with them has been reasonably satisfactory.

The straight chromium stainless alloys, such as Types 405,* 410, 430 and 442 (20% Cr) often provide adequate corrosion resistance and in other instances are a reasonable compromise between carbon steel and the 18-8 type alloys — particularly where iron contamination, product discoloration and similar factors are the concern rather than general corrosion. It has been noted that the straight chromium alloys are less subject to pitting and stress-corrosion cracking than the 18-8 alloys, particularly in certain environments where chlorides are present; this should be of continued interest both from direct application and as an alloy research and development problem.

Fortunately, there was previous experience with the use of the straight chromium alloys, particularly the Type 430 and the requirements for heat treatment of welded equipment were pretty well understood and adopted. The commercial production of the Type 405 alloy, which does not develop the embrittlement incidental with welding that most of the other 400 series stainless alloys do, was a timely and welcome improvement for use where heat treatment was impractical or undesirable.

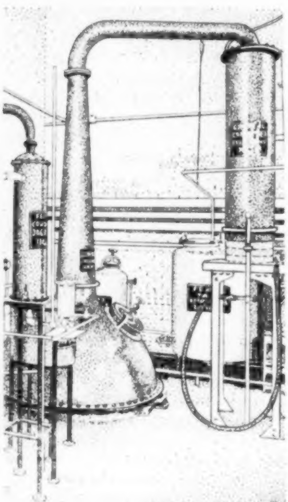
The presence of nickel in stainless alloys certainly pro-

*Merrill A. Scheil described Type 405 with chromium on the low side as a most satisfactory lining for petroleum refinery vessels in *Metal Progress*, July 1947, p. 91.

Good for Nitric Acid

vides many desirable properties not available in the straight chromium stainless alloys, giving not only improved corrosion resistance but better mechanical properties at both high and very low temperatures. Therefore the lifting of restrictions on the use of nickel will be most welcome when it comes.

L. R. HONNAKER
Consultant, Engineering Materials
Engineering Service Division
E. I. du Pont de Nemours & Co.



Does Not Contaminate Mildly Corrosive Solutions

WILMINGTON, DEL.

Principal service conditions in the chemical industry for which the straight chromium (400 series) alloys can be readily substituted for the austenitic stainless steels are probably *(a)* applications in which nitric acid is handled at relatively low temperatures, and *(b)* certain services involving only mildly corrosive conditions where freedom from contamination is the main concern.

In contrast to most European and some American practice, we have employed 15 to 16% chromium steel for much of the equipment for the production of nitric acid by the ammonia oxidation process. The composition chosen is within the range of Type 430 and was adopted as the best compromise for the particular service conditions involved between corrosion resistance, ease of fabrication and mechanical properties. The first installations of this alloy in absorption towers operating at atmospheric pressure were made in 1927 and 1928. As the process was converted to pressure operation, 15 to 16% chromium steel was also used for air heaters, preheaters, converters, cooler-condensers, bubble-cap absorption towers, storage tanks and connecting lines. With few exceptions performance has been entirely satisfactory and much of the original equipment is still in service.

Fabrication is readily accomplished with reasonable care in welding, followed by heat treatment of the welded assembly at 1400 to 1450° F. This postfabrication heat treatment is necessary to assure both maximum corrosion resistance and adequate mechanical properties. Tank cars of the same material are commonly employed for shipping nitric acid. Resistance of properly heat treated Type 430 to any concentration of nitric acid up to about 95% is excellent at atmospheric temperature, up to about 20% concentration at the boiling point, up to about 40% at 158° F., and up to about 70% at 140° F. The austenitic alloys have a higher limiting temperature in intermediate and high acid concentrations up to 95%.

Substitution of the 400 series alloys for the austenitic stainless steels is much more questionable for services involving mixtures of nitric and sulphuric acids. There are a few instances, however, where this can be done to advantage. For example in the wooden boiling tubs used in smokeless powder production, Type 443 hardware has been found to be considerably more resistant to a dilute mixed acid condition than any of the austenitic alloys.

It is not possible to generalize on the possibility of substitution of the straight chromium alloys for the austenitic stainless steels in the many and widely varied conditions involving organic acids and complex mixtures for which the latter are commonly employed. In applications involving severely corrosive conditions, the straight chromium alloys would not be satisfactory, but in some of the milder conditions substitutions are undoubtedly possible. Unless prior experience is available, corrosion tests must be made to determine their suitability. However, there are instances where austenitic alloys are used to guarantee against contamination even though corrosion may be essentially limited to moist atmospheric conditions. For such uses, Type 430 should be adequate and, depending upon requirements, even Type 410 might be suitable.

M. H. BROWN
Supervisor
Materials of Construction Section
Engineering Research Laboratory
E. I. du Pont de Nemours & Co.

Gives Adequate Service in Nitric Acid and Ammonia Plants

PITTSBURG, KAN.

We are using a 16% chromium steel in one of our nitric acid plants — absorption tower, condenser and much of the process piping being from this alloy. When this unit was installed, the piping was cut and welded in the field, the welds were preheated to 400° F., welded with 18-8 columbium stabilized rod and then stress-relieved for 1 hr. at 1400° F. Following the stress-relieving, the welds were cooled at a rate of 50 to 100° F. per hour to 1100° F. and then allowed to air cool to ambient temperature.

This piping has now been in service for two years and has been very satisfactory; no weld failures or corrosion of any kind have been encountered.

We also have used a chromium steel of 4 to 6% Cr with ½% Mo for the fabrication of baskets for the ammonia synthesis converter. These baskets operate at 900 to 930° F. and have proved adequate, although one weld on this material cracked during service and the material nitrided on the surface quite severely.

R. A. BYORUM
Project Engineer
Spencer Chemical Co.

Advertisement

ELECTROMET Data Sheet

A Digest of the Production, Properties, and Uses of Steels and Other Metals

Published by Electro Metallurgical Company, a Division of Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y. • In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario

How CHROMIUM and TUNGSTEN Increase Strength of High-Temperature Alloys

The aircraft field has served as an important "proving ground" for the high-temperature alloys that have been developed for gas turbines required to operate at elevated temperatures. However, these alloys are now demonstrating their superior properties for other primary power applications, including gas turbines to operate electrical generators for stationary or motive power.

While there are literally dozens of different alloys available for high-temperature use, most of them contain the alloying elements chromium and tungsten for the express purpose of enhancing resistance to scaling and increasing their hardness and strength at elevated temperatures. The amount used is generally determined by the stresses and temperatures expected in service. Other alloying metals may also be added for special purposes — such as columbium, manganese, silicon, and titanium.

Chromium and Tungsten as Strength-Builders

Even small amounts of chromium and tungsten are effective in increasing the strength of high-temperature alloys. An important consideration is, of course, the exposure time—particularly when operating temperatures go above 1200 degrees Fahrenheit. Although the major role of chromium is to prevent scaling, it has been found that chromium, as well as tungsten, also helps the alloys to maintain their strength when they are exposed to high temperatures for long periods of time.

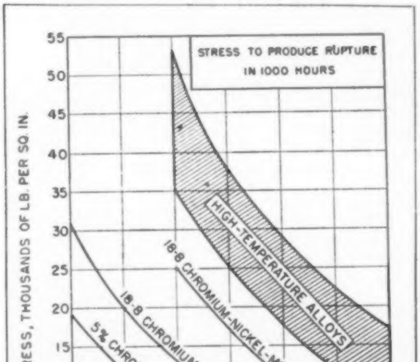


Fig. 1—Here is the average range of strength of various high-temperature alloys compared with other metals.

In addition to chromium and tungsten, the combination of other alloying metals present will likewise influence the strength of the alloys. Heat-treatment, too, will influence the properties of these materials. However, in obtaining the higher ranges of strength needed at extremely high temperatures, chromium and tungsten are essential.

Where High-Temperature Alloys Are Used

Special high-temperature alloys containing chromium and tungsten are being used for the construction of gas turbines that power railroad locomotives, ships, airplanes, and electric generating plants. Some typical parts made of these alloys are rotors, turbine blades, nozzle vanes, ducts, and housings. These parts are exposed to temperatures of from 1200 to 1500 degrees Fahrenheit.

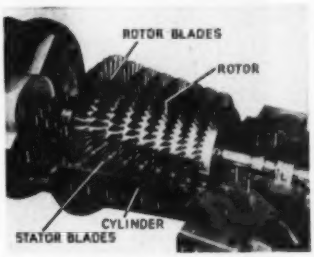
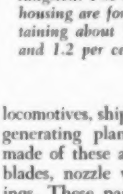


Fig. 2—Rotor and stator blades in this locomotive-type gas turbine are precision-cast of an alloy containing about 24 per cent chromium and 6 per cent tungsten. The rotor body and cylinder housing are forged from an alloy containing about 19 per cent chromium and 1.2 per cent tungsten.

If You Need Technical Help

Those producing high-temperature alloys who wish technical help in the selection of alloying metals will find ELECTROMET's metallurgists glad to cooperate. In addition to chromium and tungsten alloys, ELECTROMET also produces ferro-alloys of columbium, manganese, silicon, and titanium for use in making high-temperature alloys. If you wish further information about the properties and uses of these alloys, write to the nearest ELECTROMET office.



Ask for our booklet "Electromet Products and Service." It describes over 50 metals and alloys produced by ELECTROMET and tells of the unique technical service offered to the metal industries.

Personal Mention

John Frye

Lester A. Shea

JOHN FRYE, colonel in the U. S. Army Ordnance Corps, has completed a tour of duty in Washington and has been reappointed manager of sales at Columbia Steel & Shafting Co. and its Summerill Tubing Co. division, Carnegie, Pa. Except for two absences when he was on Army duty, Col. Frye has been associated with Columbia since 1928. He graduated from Ohio State University in 1925 and after two years with Wheeling Steel Corp. as a metallurgist, entered Columbia's employ as assistant plant metallurgist. In 1931 he went to the company's Detroit office as a special representative, returning in 1937 to become chief metallurgist. In 1940 he relinquished that position to become a colonel in the Army. After the war Col. Frye rejoined his old associates, becoming Columbia-Summerill's manager of sales in 1946 and continuing in that capacity until early 1950. At that time he returned to Washington, serving as deputy executive officer to the chief of ordnance, with headquarters in the Pentagon.

T. L. Joseph, assistant dean of the School of Mines and Metallurgy at the University of Minnesota, was recently elected to the board of directors of the Engineering College Research Council of the American Society for Engineering Education.

LESTER A. SHEA, on leave of absence as general sales manager of Lindberg Engineering Company, Chicago, has been selected chief, industrial heating equipment section, metalworking equipment division, of the National Production Authority, Washington, D. C. He has 27 years of experience in the industrial heat treating and melting field which he has brought to his new assignment as an industrial advisor to the government. Mr. Shea received his formal education of engineering and business management at the School of Engineering and the Milwaukee branch of the University of Wisconsin. He has held responsible positions in design engineering, furnace field erection and district office management in the industrial heating field before he joined Lindberg Engineering in 1937, where he is now on the executive staff and design committee. He serves directly as the coordinator for various Lindberg divisions. In addition he is engaged in all advertising, sales promotion, publicity and government requirements on pricing and renegotiation. He is a member of the American Foundrymen's Society, Sales Executive Club of Chicago, and American Institute for Management. He served five years on the executive board of the Chicago Chapter, two of them as its secretary-treasurer.

Gorham W. Woods has joined Republic Hardfacing Corp., Bedford, Ohio, as engineer in charge of the newly created industrial hardfacing division. He will also advise on problems of heat and wear resistance. Mr. Woods was development engineer at Lincoln Electric Co., Cleveland, for the past seven years, and previous to that was on the engineering staff of Hughes Tool Co., Houston, Texas, for 21 years. He is a pioneer in the hardfacing field and holds a number of patents on welding material and procedures.

Gordon E. Dunlap has been appointed chief, metallurgical branch, production division, New York operations office, U. S. Atomic Energy Commission. He has been a member of the New York staff for the past year, and for six years prior to that was a development metallurgist at American Brake Shoe Co., New York. During World War II, at the Metals Disintegrating Co., Elizabeth, N. J., he worked on projects for the Manhattan Engineer District, and from 1934 to 1943 he was with American Steel & Wire Co. Mr. Dunlap received his B.S. and metallurgical engineering degrees from Columbia University. He is a member of the American Institute of Mining and Metallurgical Engineers and an associate member of the Bristish Iron and Steel Institute.

Charles D. Townsend has been appointed director of manufacturing at LaPointe-Plascomold Corp., Rockville, Conn.

Joseph F. Boyce has transferred from the research laboratory of U. S. Steel Co., Kearny, N. J., to the research and development laboratory of the same company in Pittsburgh.

Harold E. Trent, of Media, Pa., has left for Europe for a business and pleasure trip. Mrs. Trent has accompanied him and they will remain abroad until August 1953.

Helmut Thielsch, formerly of the Welding Research Council, has been appointed to the position of director of applied welding engineering at Eutectic Welding Alloys Corp., Flushing, N. Y. He will also be a member of the research team at Eutectic.

Personals

Henry H. Hausner ⊕, metallurgical scientist of Sylvania Electric Products Inc., Bayside, N. Y., returned from Europe recently where he attended three international conferences on powder metallurgy. He was an observer at the International Metallurgy Congress in Stockholm, served as chairman of the powder metallurgy session at the international symposium on the reactivity of solids in Gothenberg, Sweden, and was one of the principal speakers at the Plansee seminar on metallurgy in Reutte, Tyrol, Austria. Dr. Hausner is a fellow of the New York Academy of Science and is chairman and secretary of the powder metallurgy group of the American Institute of Mining and Metallurgical Engineers.

Edward L. Bartholomew, Jr., ⊕, associate professor of mechanical engineering at the University of Connecticut where he is in charge of metallurgy and is supervising research on titanium for Army ordnance, was awarded a D.Sc. degree from Massachusetts Institute of Technology. Dr. Bartholomew conducted research and taught courses in mechanical metallurgy at M. I. T. from 1938 to 1950.

Stanley Craig Orr ⊕ has been appointed assistant factory manager of Pfaudler Co.'s Elyria (Ohio) division. A graduate of Alfred University with a B.S. degree in ceramic engineering, he began his career with the company in 1937 as assistant ceramist. He became chief ceramist in 1947, a position he held until his recent appointment. Mr. Orr is the author of many articles on ceramic testing procedures and the metallurgy of stainless steels.

Robin O'Dare Williams ⊕ has been appointed to the staff of Oak Ridge National Laboratory, operated by Carbide and Carbon Chemicals Co., a division of Union Carbide and Carbon Corp.

Joseph A. Rosa ⊕, formerly with the alloy steel division of Republic Steel Corp., has joined Burke Steel Co., Rochester, N. Y., as manager of forging sales.

Edward S. Coe ⊕, recently research engineer in manufacturing research at the Ford Motor Co. Rouge plant, is now manager of chemical engineering at the Ford Highland Park plant.

Personals

Don T. Galvin ⊕ has been appointed a representative of Harbor Mfg. Co., Oak Harbor, Ohio, in the Detroit area.

Edward J. Roehl ⊕, manager of technical development for the Thomas Strip Division of Pittsburgh Steel Co., Warren, Ohio, was awarded a silver medal by the American Electroplaters Society at the annual convention for his co-authorship of a paper on "Nickel Plating With Insoluble Anodes". The work shows how distinct engineering advantages are gained by replacing conventional nickel anodes with insoluble anodes and replenishing the metal in an auxiliary tank rather than in the plating bath. A patent has been granted covering this process.

Elmer A. Terwell ⊕ is now representing Standard Alloy Co., Inc., Cleveland, in Illinois and northern Indiana.

John D. Seaver ⊕ has been named assistant manager of engineering of General Electric Co.'s industrial heating department at Schenectady, N. Y. After receiving his B.S. degree in physical metallurgy from Massachusetts Institute of Technology in 1935, Mr. Seaver became one of the initial candidates in the G. E. chemical and metallurgy program. Later he joined the staff of the meter and instrument laboratory where he worked in metallurgy until his appointment as engineer in 1947.

George Sachs ⊕, formerly with Horizons, Inc., Cleveland, is now research professor and director of metallurgical research at Syracuse University.

James F. Puhl ⊕ has been named assistant sales promotion manager of Follansbee Steel Corp., Pittsburgh. He was formerly an account executive with Ketchum, MacLeod & Grove, Inc., Pittsburgh.

D. G. Clark ⊕ has been appointed assistant general sales manager of Firth Sterling, Inc., Pittsburgh. His association with the company began in 1903 and continued until 1946 when he retired from active management but remained as consultant on sales until 1950. He has been succeeded in the position of steel sales manager by **E. William Kalb** ⊕, who was formerly assistant manager of the steel sales division.

Personals

Carmen L. Adovasio ⊕, for the past 11 years metallurgical engineer at Ohio Brass Co., Mansfield, Ohio, has accepted a position with Cia. Industrial Del Norte, S. A., Mexico, where he will serve as production and technical advisor in the castings division. He was also elected a director of the Mexican firm.

Leo P. Sinclair ⊕, formerly with the Navy Bureau of Ordnance, is now liaison engineer handling technical and contractual matters for the Daco Machine and Tool Co., Brooklyn, N. Y.

Charles G. Gribble, Jr., ⊕ has been appointed manager of sales at Metal Goods Corp., Houston, Texas, division. He has been with the corporation since 1946 and formerly was foundry superintendent at the U. S. Naval Repair Base, San Diego, Calif.

Xarifa and Morris Bean ⊕ received honorary degrees of doctors of science from Antioch (Ohio) College in recognition of their outstanding contributions in the scientific advancement of precision casting of metals. They were the first husband and wife team to be so honored by Antioch. Mr. and Mrs. Bean are members of the executive board of Morris Bean and Co., precision-casting foundry at Yellow Springs, Ohio.

Edward H. Platz, Jr., ⊕, alloy sales manager of the Lebanon (Pa.) steel foundry, has been assigned to the nickel section, ferro-alloys branch, National Production Authority, in Washington. His tour of duty is expected to be six months, after which he will resume his regular duties at Lebanon Steel Foundry.

F. S. Blackall, Jr., ⊕, president and treasurer of Taft-Peirce Co., Woonsocket, R. I., has been nominated as 1953 president of the American Society of Mechanical Engineers. Since only one name is presented for office, nomination is tantamount to election. Mr. Blackall, an alumnus of Yale and Massachusetts Institute of Technology, was a member during World War II of the War Production Board; the U. S. Navy War Manpower Survey Committee, First Naval District; and the Precision Tools and Machine Tool Industry Committees. He has been with Taft-Peirce since 1922.

Personals

Verne Pulsifer ⊕, chief metallurgist for Olin Industries, Alton, Ill., and past chairman of the St. Louis, Mo., chapter of the American Society for Metals, has been appointed a supervisor in the metals department of Armour Research Foundation of Illinois Institute of Technology. **Frank A. Crossley** ⊕, head of the department of foundry engineering at Tennessee A. & I. University, Nashville, Tenn., has been appointed an associate metallurgist in the same department.

Weaver E. Falberg ⊕, assistant manager of the alloy steel division of Joseph T. Ryerson & Son, Inc., Chicago, has been promoted to manager of the division. He will have the responsibility of coordinating alloy steel sales in all areas served by the firm's group of 15 steel service plants.

G. Howard LeFevre ⊕ has been elected vice-president and manager of metal sales, U. S. Smelting, Refining and Mining Co., Inc., New York. Mr. LeFevre is well known for his work in the American Society for Testing Materials.

Howard H. Casey ⊕, formerly director of aircraft forging sales with Camden (N. J.) Forge Co., has joined Midvale Co. as general sales manager for its Nicetown, Philadelphia, plant.

C. H. Wyman ⊕, superintendent of melting, Burnside Steel Co., Chicago, was elected vice-president of the Electric Metal Makers Guild for 1953. **C. B. Williams** ⊕, superintendent of melting, Massillon (Ohio) Steel Casting Co., was reelected secretary-treasurer.

W. P. Woodside, Jr., ⊕, Cleveland, and **Robert N. Lynch** ⊕, Detroit, were voted directors of Park Chemical Co., Detroit.

Henry S. Freynik ⊕ has been elected vice-president of Riverside (N. J.) Metal Co. He has been with the company since 1923 and has been chief metallurgist for the past 12 years. As a specialist in nonferrous metals, he was a conferee at the World Metallurgical Congress in Detroit last October.

Allen E. Richt ⊕, formerly of the University of Cincinnati, has recently been appointed to the staff of the Oak Ridge National Laboratory, operated by Carbide and Carbon Chemicals Co., a division of Union Carbide and Carbon.

Nature of Bainite*

EXAMINATION of bainitic structures in eutectoid steel by optical microscopy at 2500 diameters fails to resolve the fine details, and a series of samples of 0.87% C steel (containing 0.44% Mn, 0.39% Ni and 0.21% Cr) were isothermally transformed at various temperatures between 500 and 950° F. and studied by the replica technique at 15,000 diameters.

When the steel is transformed at 950° F., much of the structure consists of fine pearlite (relatively parallel platelets of ferrite and carbide) and a little of the latter coexists with "upper bainite" in samples transformed at 850° F. A series of specimens held for increasing times at 850° F. shows that the upper bainite "feathers" are long, parallel carbide stringers in a ferrite matrix. These apparently grow from a single plate, and extend from the pointed end of a "needle" whose tip is ferrite with little or no carbide. Single or multiple plates of carbide are generally sheathed in ferrite. After reaching a certain length the bainitic areas appear to broaden more rapidly than they extend, and frequently assume a radiating rather than a parallel orientation. When such a mass is sectioned at an oblique angle, the structure may approach that of fine pearlite. The carbide is presumably cementite, Fe_3C.

Upper bainite transformed at lower temperatures consists of progressively finer structures; the "feathers" also were found to have relatively smaller areas in the microsection.

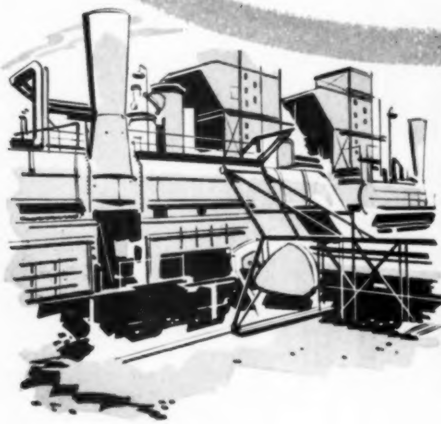
"Lower bainite" in this steel appears during isothermal transformation between 600 and 650° F., and is the prevailing structure down to the M_s point, the beginning of martensite formation (somewhat less than 500° F. in this steel). It consists of ferrite "slabs" (appearing as needles in the plane of polish) within which are parallel platelets of carbide oriented at about 55° to the needle axis. The carbides show electron diffraction lines characteristic of cementite, Fe_3C, if transformed at temperatures in the upper portion of the 500 to 600° range; if transformed in the lower portion, nearer the M_s point, some hexagonal ϵ-iron carbide is present.

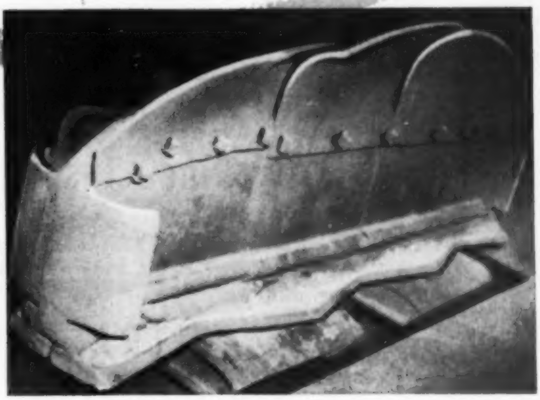
E. E. T.

*Abstract of "Progress Report of Subcommittee XI of American Society for Testing Materials' Committee E-4 on Metallography", Preprint for 1952 general meeting (see also A.S.T.M. *Bulletin*, May 1952, p. 62).

These Hard-Faced Coke Pusher Shoes Lasted Over Two Years

STEEL SHOES WORE OUT IN TWO MONTHS





Riding over the coke-covered floor of an oven wears out plain steel pusher shoes in only two months. Hard-faced shoes have lasted at least two years, despite the severe abrasion, heat, thermal shock, and erosion involved in operation. With minor repairs, the hard-faced shoes can be used for another two or three years.

HAYNES STELLITE No. 1 hard-facing rod was selected to protect these shoes because it is hard enough to resist abrasion from the coke particles and the lining of the oven floor. It does not chip or spall under the thermal shock of returning from 1800 deg. F. in the oven to atmospheric temperatures.

There is a complete line of HAYNES hard-facing materials to choose from. Each is particularly suited to combat certain conditions of wear, heat, corrosion, or erosion. For a quick summary of the properties and forms of the various HAYNES rods, write for "HAYNES Hard-Facing Materials Data."

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Electrotinning Copper Wire in Alkaline Bath*

A FAST AND EFFICIENT process for electrotinning copper wire, using a potassium stannate bath, appears to offer a number of advantages over earlier methods. Speeds on the order of 600 ft. per min. on 18-gage (0.040-in. diameter) wire, with tin thickness of 20 millionths (0.000020-in.) appear practicable in a tank length of 20 ft., this requiring a current density of 558 amp. per sq.ft. at 100% current efficiency and operating temperature of 194 to 203° F.

Plating solution is of high concentration — 67 to 84 oz. per gal. of potassium stannate, 2 to 3 oz. per gal. of free potassium hydroxide, along with a foaming agent such as potassium oleate to reduce spray. Anodes such as the high-speed type made by Metal and Thermit Corp. are recommended, because they dissolve better than pure tin and do not require as much overpotential to film them.

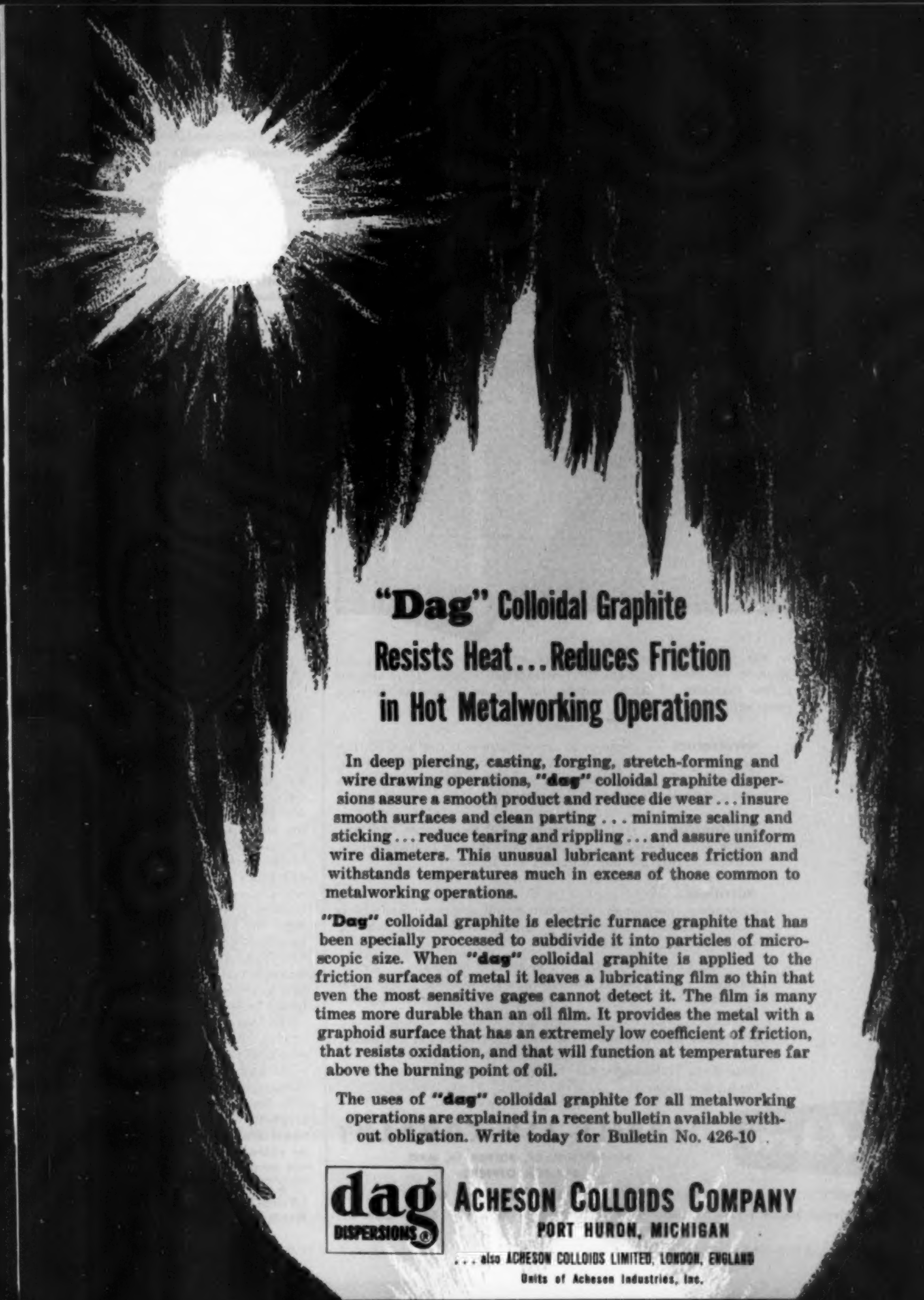
While alkaline stannate solutions require rather high temperature, they have many offsetting advantages, including: Simplicity of composition, no organic addition agents, no critical features, ease of analytical control, high tolerance for impurities, high throwing power, detergent action, no corrosion problems and a fine-grained deposit with good solderability.

Most tinned copper wire must meet certain specifications, among which is the A.S.T.M. dip test in polysulphide solution. Assuming a sound coating, a thickness of about 15 millionths in. is sufficient to pass this test (two dips). Hot dipped wire may have coatings as thick as 80 to 100 millionths, because it is both difficult to wipe the wire consistently to realize thinner coatings, and also to insure that the thinnest points will meet the test. In contrast, electroplated wire can be produced with a coating of 20 millionths and no excess tin required for insurance against thin spots. The advantages of saving this amount of tin are obvious, particularly in these days of critically short metal supplies.

As in all types of commercial tin plating solutions, the deposit from the potassium stannate solution is a matte rather than bright finish. If a bright finish is de-

(Continued on p. 128)

*Abstract of "Electrotinning Copper Wire: A New Process, Part I — The Process", by Frederick A. Lowenheim, *Wire*, May 1952, p. 464.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In deep piercing, casting, forging, stretch-forming and wire drawing operations, "dag" colloidal graphite dispersions assure a smooth product and reduce die wear ... insure smooth surfaces and clean parting ... minimize scaling and sticking ... reduce tearing and rippling ... and assure uniform wire diameters. This unusual lubricant reduces friction and withstands temperatures much in excess of those common to metalworking operations.
"Dag" colloidal graphite is electric furnace graphite that has been specially processed to subdivide it into particles of microscopic size. When "dag" colloidal graphite is applied to the friction surfaces of metal it leaves a lubricating film so thin that even the most sensitive gages cannot detect it. The film is many times more durable than an oil film. It provides the metal with a graphoid surface that has an extremely low coefficient of friction, that resists oxidation, and that will function at temperatures far above the burning point of oil.
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Electrotinning Copper Wire in Alkaline Bath

(Continued from p. 126)

manded, the wire can be passed through a die to reduce the diameter by one mil or less. "Heat flowing" is another brightening method.

Cleaning before plating is simple. The wire is passed through a 5-ft. tank where it is cleaned by cathodic current in a solution of caustic soda and sodium cyanide. A short water rinse is interposed between cleaning and plating. Since the cleaning solution is inexpensive, there is no need to attempt drag-out recovery.

Concentration of the plating solution makes its recovery from the first rinse tank advisable, this being accomplished readily by returning the rinse solution to the plating tank or recirculating it through a storage tank. Steam is the principal component of fumes from the plating tank, plus minor quantities of caustic spray. They can be kept to a minimum by the use of covers over the solution and one or two strategically placed ventilating fans.

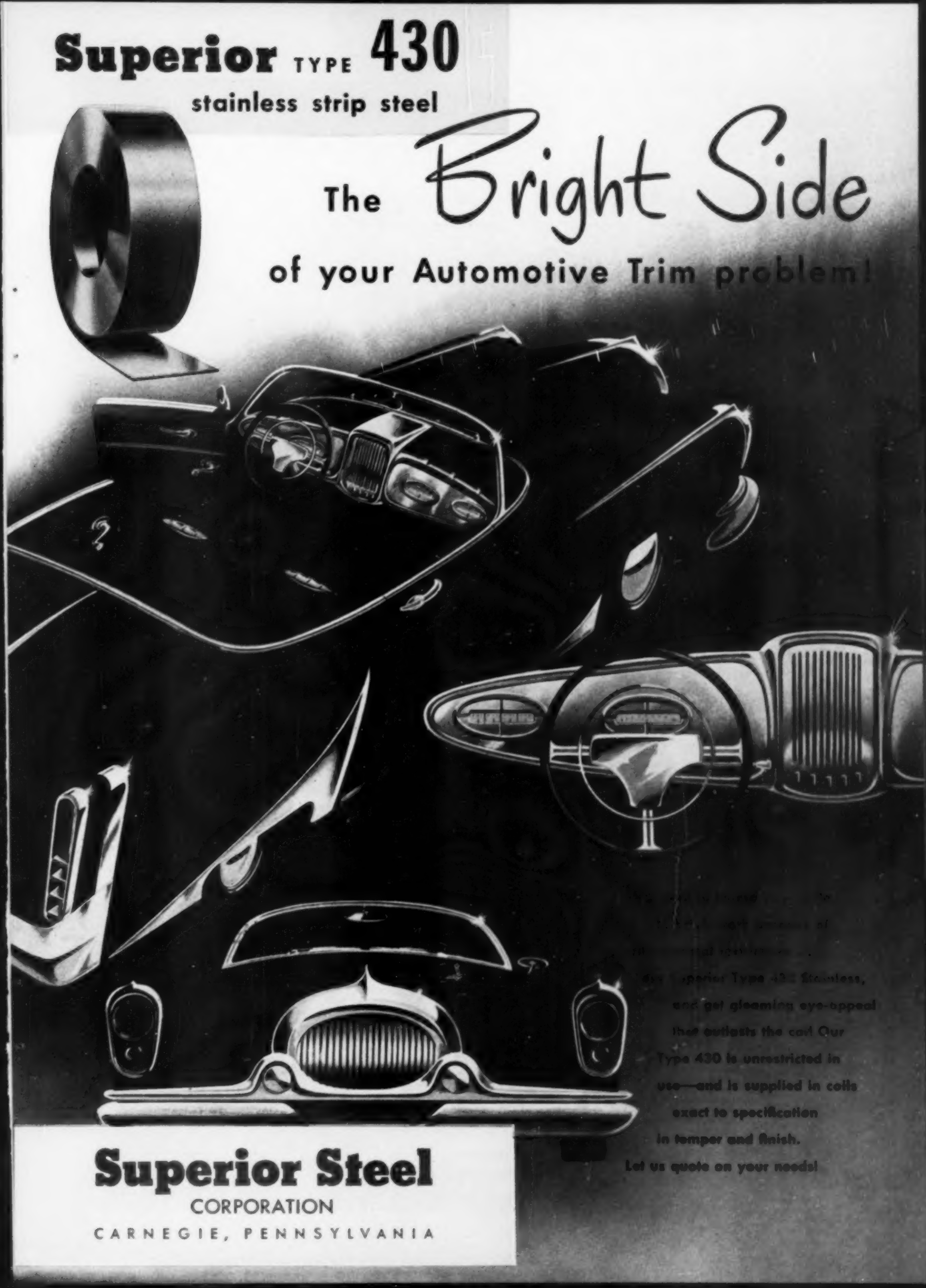
A. H. Allen

Degassed Metals*

Appearance of this article is most timely because of the increasing interest in degassed metals. The alloys treated were monel (33% Cu, 67% Ni, 1.5% Si); nickel bronze (47% Cu, 35% Ni, 11% Sn, 7% Pb); leaded bronze (84% Cu, 8% Sn, 6% Pb, 2% Zn); and nickel-silver (52.5% Cu, 20% Ni, 1.5% Sn, 6% Pb, 20% Zn). The nickel-bearing alloys were degassed with magnesium, but this treatment left gas in the metal which showed up as fine holes after machining. Also, a scum covered the surface of the molten metal after the addition. After the addition of lithium to the skimmed and deoxidized melt, the film produced by the magnesium was eliminated, as was the gas. The best average amount of lithium was found to be 0.005%.

In the treatment of leaded bronze, 0.04% phosphorus was added as usual for deoxidizing purposes and this was followed by the lithium. The metal was completely free from gas. Test-bar molds of graphite were used for casting the metal and piping was produced to an extent never seen in the alloys not treated with lithium.

*Abstract of "Degassing With Lithium", *Metal Industry*, Vol. 80, March 7, 1952, p. 191.



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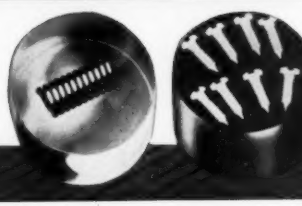

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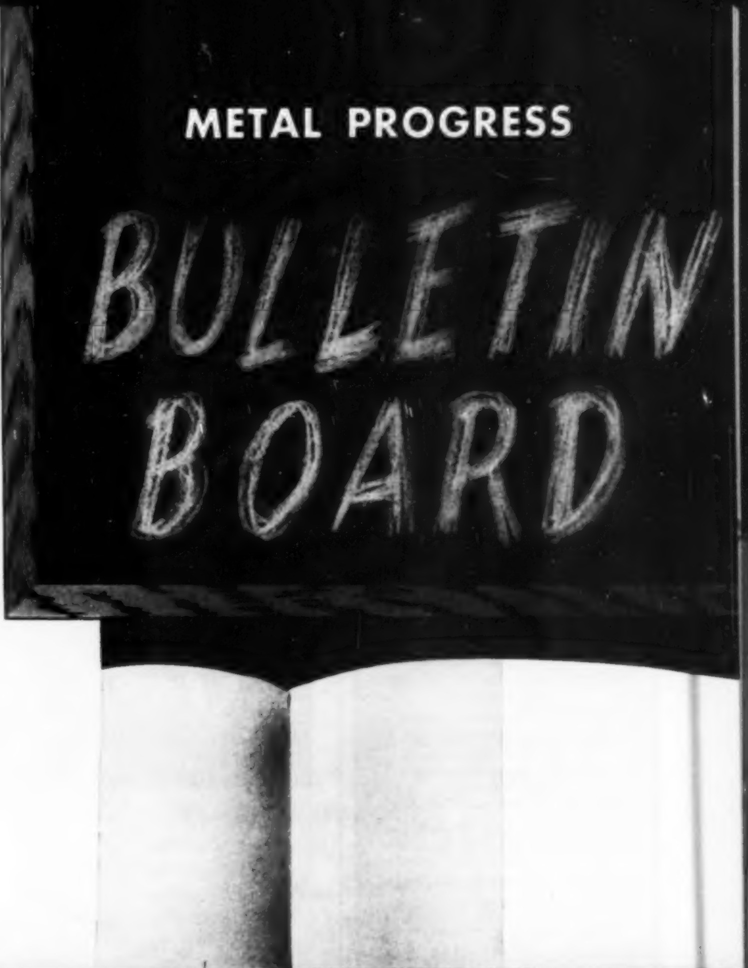
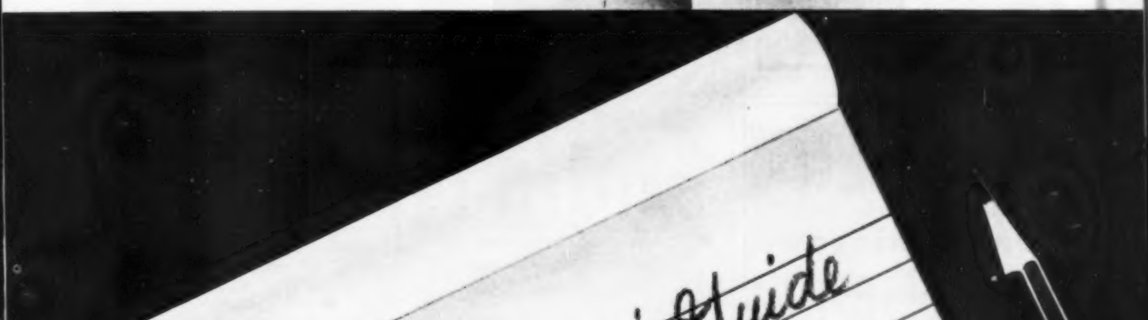


METAL PROGRESS
BULLETIN BOARD



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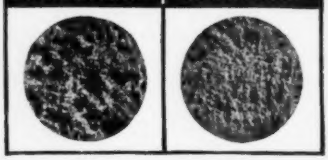

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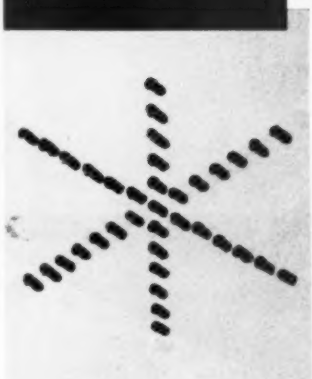

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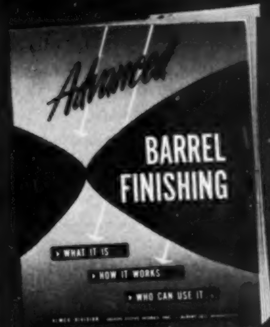

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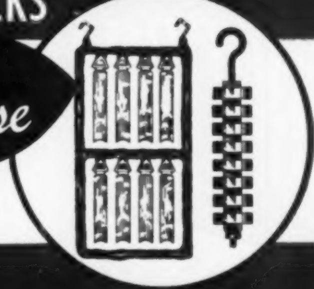

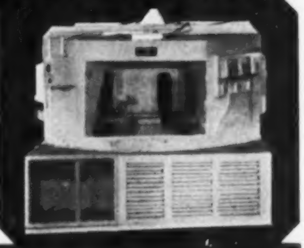

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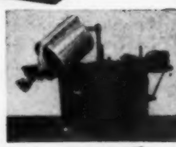

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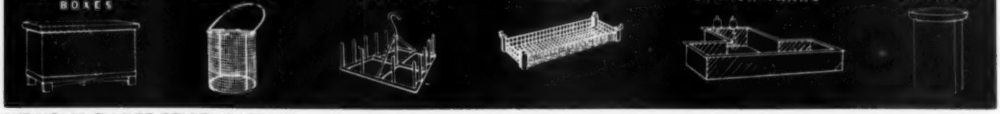

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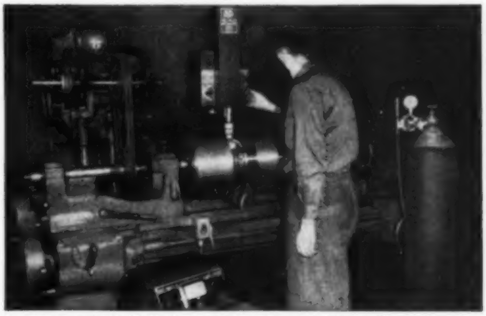

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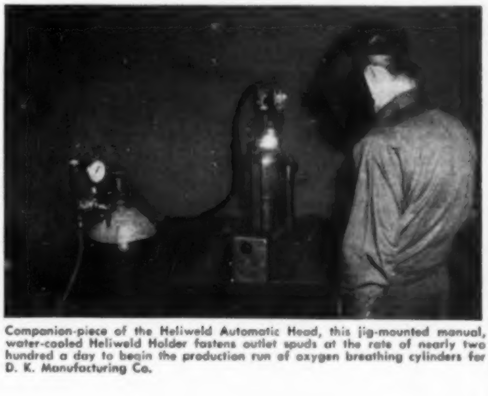

Companion-piece of the Heliweld Automatic Head, this jig-mounted manual, water-cooled Heliweld Holder fastens outlet spuds at the rate of nearly two hundred a day to begin the production run of oxygen breathing cylinders for D. K. Manufacturing Co.

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Aluminum Alloys of High Modulus*

Before 1947 it was found that failures of aircraft structures were often due to elastic instability of compression members, and the Young's modulus (or modulus of elasticity) is one of the main factors governing this property. In the paper "The Young's Modulus of Some Aluminum Alloys", by N. Dudzinski, J. R. Murray, B. W. Mott, and R. Chalmers (*Journal*, Institute of Metals, Vol. 74, 1948), it was disclosed that silicon, manganese, nickel, cobalt or beryllium additions to aluminum appreciably improve this modulus of elasticity in tension.

On the basis of that conclusion, sheets were ordered by the Royal Aircraft Establishment to demonstrate the feasibility of applying such alloys of high modulus in actual practice. Some doubt existed as to whether the high concentration of intermetallic compounds in these alloys, which appears to be the cause of the higher modulus, would not interfere too much with the casting, hot-working, and ordinary tensile properties. The present paper gives the results of a metallurgical examination of the sheets, including hardness, tensile, compression, bend and Erichsen tests.

Most of the tests were made on an alloy containing 10.4% silicon, 3.72% copper, 2.06% nickel, 0.53% manganese, 0.35% iron, 0.27% magnesium, 0.13% cobalt, 0.06% titanium, and 0.002% beryllium. A few tests are also reported on two other alloys, differing from the preceding to the extent that one contained 3.02% copper, 1.11% manganese, and no nickel, and the other 2.0% copper, 1.04% manganese, and 1.90% nickel.

Sheet production was successful, using the same care as required for the very high-strength aluminum alloys. The two alloys with over 3% Cu hardened from about 95 Vickers to about 135 on aging 40 hr. at room temperature after water quenching from 510° C.; the alloy with 2% Cu hardened less. The latter was also considerably weaker than the former two alloys when tested in tension after heat treat-

(Continued on p. 144)

*Abstract of "Development of Aluminum Alloys Having a High Young's Modulus", by G. Meikle, J. Thompson and M. E. Whillans, Technical Note No. Met.-149, August 1951, Royal Aircraft Establishment, Farnborough, Hants, England.

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Aluminum Alloys of High Modulus

(Continued from p. 142)

ment, its tensile strength being about 58,000 psi., as compared with 66,000 for the first two.

All the other tests reported were made on sheets of only the first alloy (containing 3.72% Cu, 2.06% Ni, and 0.53% Mn). After solution heat treatment for 1 hr. at 510° C., quenching in cold water, and aging 24 hr. at 155° C., the tensile and compression properties averaged about as follows:

Property	Tensile Psi.	Comp. Psi.
0.1% proof	48,500	56,000
Ultimate	63,500★	—
Modulus	11,800,000	12,600,000

★The elongation was 5.5%.

There was very little difference between the 20 and 14-gage materials under tension. The transverse tensile properties were slightly lower than the longitudinal, but the compression data show a reverse relation. Aging at room temperature gave lower strength, but 10% elongation. After aging 24 hr. at 155° C., the properties were practically constant for at least 90 days at room temperature. The higher modulus in compression may have been due to test conditions.

Bend and Erichsen tests of heat treated specimens indicated no consistent changes in ductility for the samples aged between one and ninety days. Other results reported are:

Aging Temperature	Bend Radius	Erichsen Test, Mm.
70° F.	3 t.	2.49 to 3.25
155° C.★	4.5 to 5 t.	1.72 to 2.05
°C.†	4.5 to 5 t.	1.75 to 2.06

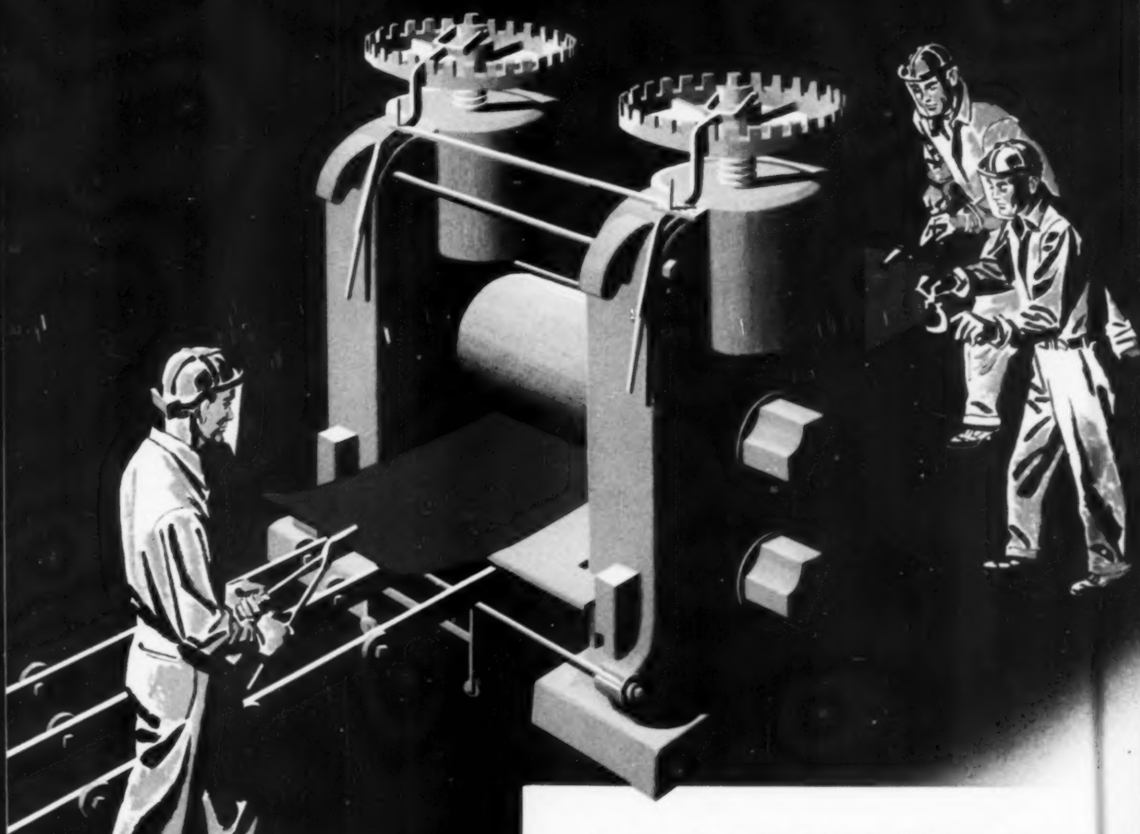
★Aged 24 hr. at 155° C., starting directly after the quench.

†Aged 24 hr. 155° C., but a period of 7 days at 70° F. intervened between quenching and the start of accelerated aging.

Microscopic examinations of polished and etched sections revealed many fine and evenly dispersed particles of $CuAl_2$ and $NiAl_3$, and a few larger particles of the Al-Ni-Cu complex. This structure was considered to be satisfactory.

Corrosion and fatigue tests were in progress when this report was written. It was planned to investigate the effect of changes in composition including higher manganese, nickel, cobalt, or iron, and the addition of vanadium and chromium respectively.

G. F. Comstock



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Effect of Deformation on Transformation of Austenite to Martensite*

In explaining the effect of plastic deformation on the transformation of austenite to martensite, it is usual to start with a picture of this process as a purely mechanical phenomenon, similar to twinning, and to consider that the formation of martensite during the deformation process supports this point of view. However, because of the new conception of the nature of the martensite transformation and new data on its kinetics (see abstract p. 122, January 1952 issue of *Metal Progress*), the effect of deformation can be thought to be a result of its influence on the processes of nucleation and growth of martensite crystals. In this connection it is essential to study the effect of deformation during extreme cooling, and especially on the rate of isothermal transformation and on its temperature dependence.

Such an investigation was carried out on a steel of 0.6% C, 7.1% Mn and on an iron alloy containing 23% Ni and 3.4% Mn. Both the steel and the carbon-free alloy have their martensite points 10 to 100° C. below room temperature. Plastic deformation was carried out at room temperature by compression and was followed immediately by testing in a magnetometer. The plastically deformed specimens were then cooled to cause the martensite reaction to occur, and the progress of reaction was followed by magnetometer readings. These data were verified by X-ray and metallographic studies.

Comparison of the cooling curves from deformed and undeformed specimens showed that in all instances a deformation of 25 to 30% had a strong influence both on the structure of the specimen immediately after deformation and on the behavior during subsequent cooling. Also, such deformation caused the formation of 10 to 20% martensite during loading, and greatly increased the stability of the deformed, untransformed gamma phase. The rate of transformation in the steel decreased to one third of the value characteristic of the undeformed steel, while in the alloy the rate decreased to one tenth of the original value. At a given degree of cooling a greater amount of the undeformed

(Continued on p. 148)

*Abstract of "Transformation of Deformed Austenite Into Martensite", by G. V. Kurdyumov, O. P. Maksimova, and T. V. Tagunova, *Doklady Akademii Nauk SSSR*, Vol. 73, 1950, p. 307.

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Transformation of Austenite to Martensite

(Continued from p. 146)

alloy had transformed to martensite. Thus, although some martensite could be produced during deformation, this factor was more than offset by the increased stability of the remaining gamma phase. In the carbon-free alloy, transformation on cooling was delayed only by the slower reaction rate. However, in the steel the martensite point was lowered also by deformation, the decrease being greater with higher carbon content.

Investigation of the steel gave the following results (which are partially summarized in Fig. 1 and 2): Small amounts of plastic defor-

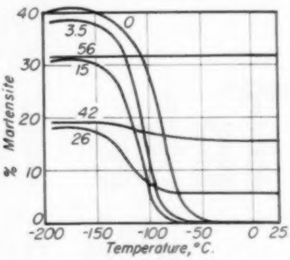

Fig. 1 — Influence of Deformation (Values on Curves Are Percentage of Deformation) on the Transformation of Austenite to Martensite During Continuous, Deep Cooling at 10° C. per Min. Steel containing 0.6% C, 7.1% Mn

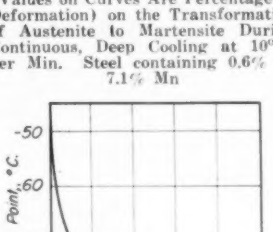

Fig. 2 — Influence of Degree of Deformation on Martensite Point (the Temperature of the Beginning of Transformation). Same steel as reported in Fig. 1

mation, about 3%, produced no transformation during loading, but made subsequent transformation on cooling more sluggish and lowered the martensite point 20 to 25° C. Transformation to martensite during loading began between 5 and 10% deformation. After 50 to 70% de-

(Continued on p. 150)

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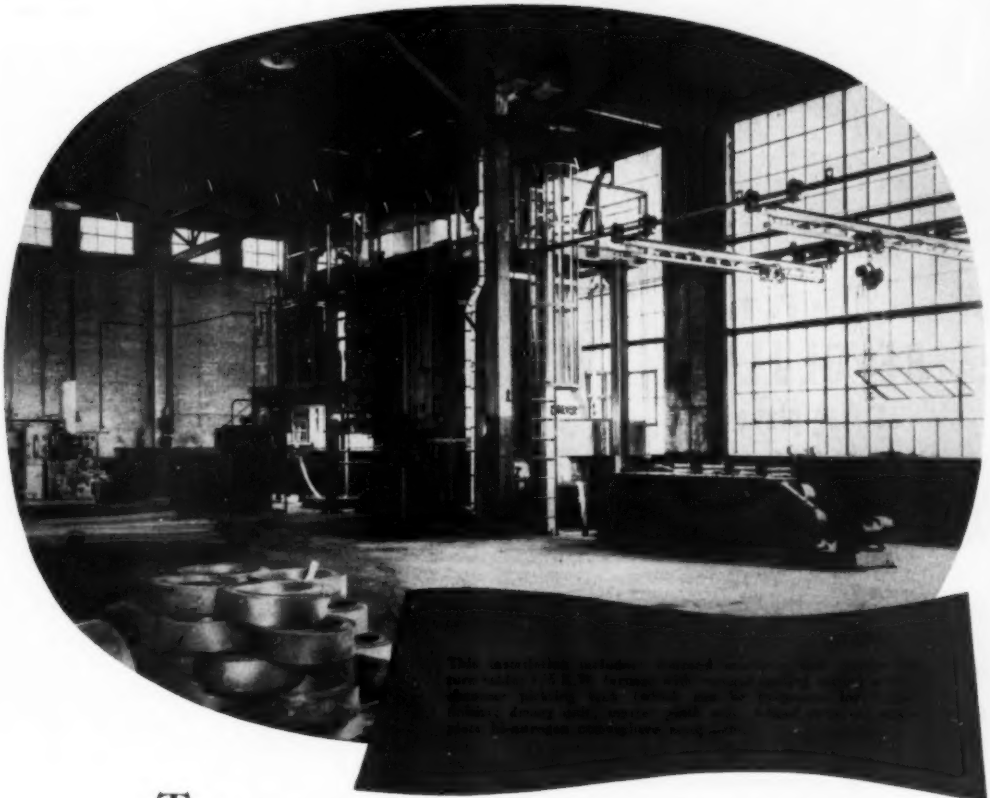

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Transformation of Austenite to Martensite

(Continued from p. 148)

formation no additional transformation to martensite occurred during subsequent cooling. Continuous lowering of the martensite point occurred up to about 30 to 40% deformation, Fig. 2.

It was found that the total martensite produced as a result both of deformation and of cooling decreased up to 20 or 30% deformation. It then increased again and, after large amounts of deformation, approached the value of the undeformed alloy.

In the nickel-manganese alloy the effects of deformation were still more pronounced. After 15 to 20% deformation only about one fourth as much transformation to martensite occurred as was found in the undeformed alloy.

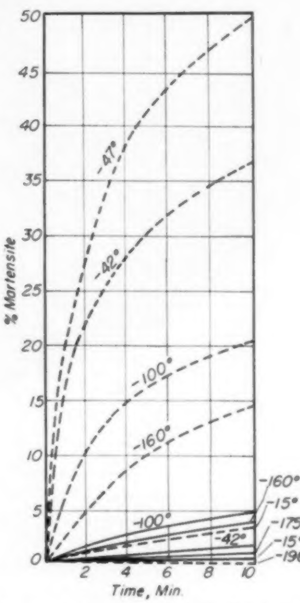

Fig. 3 — Isothermal Transformation of Martensite at Various Temperatures (°C.) for Specimens Deformed 14% (Solid Lines) and Undeformed Specimens (Broken Lines). Iron alloy containing 23% Ni, 3.4% Mn

The kinetics of the martensite reaction were studied on specimens of this alloy deformed 0% and 14%. The initial portions of the isothermal reaction curves at temperatures from −15 to −196° C. are shown in Fig. 3. Although both the deformed and

(Continued on p. 152)

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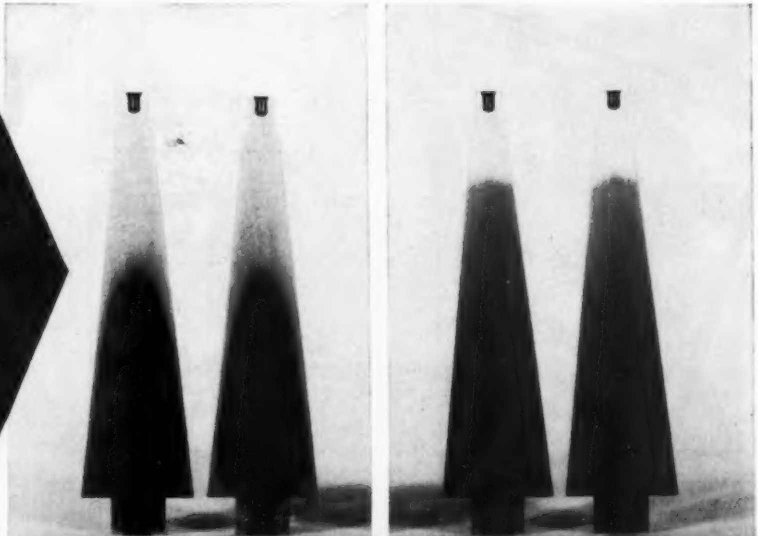

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Transformation of Austenite to Martensite

(Continued from p. 150)

the undeformed specimens finally reached about the same degree of transformation, 35% at −100° C., it can be seen that the initial rates of reaction are about ten times greater for the undeformed specimens. A plot of the logarithms of the initial

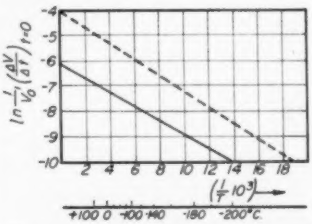

Fig. 4 — Dependence of the Logarithms of the Initial Rates of Formation of Martensite on Temperature for Specimens Deformed 14% (Solid Line) and Undeformed (Broken Line). Same alloy as for Fig. 3

reaction rates versus 1/T is shown in Fig. 4. The activation energy for both deformed and undeformed specimens is about 600 calories per mole, indicating that the nature of the martensite reaction is not greatly affected by deformation. The cause of the decrease in reaction rate is not certain, but it may be a decrease in the volume of the individual martensite crystals. A. G. GUY

Fatigue Tests at High Temperatures*

A DESCRIPTION of the machine devised for the investigation of the fatigue strengths of materials at elevated temperatures together with results obtained by its use in corrosion-fatigue testing are reported.

The machine is of the rotating beam type with single-point cantilever loading. The specimen used in the machine is 2 in. long with a ¼-in. shank diameter and a 0.160-in. throat diameter. The usual testing speed is about 5000 r.p.m., using loads up to 90,000 psi. and temperatures up to 800° C. (1470° F.).

A considerable amount of investigation has been carried out to determine a method of measuring the

(Continued on p. 154)

*Abstract of "Hot Fatigue Testing", by H. E. Gresham and B. Hall, Symposium on High-Temperature Steels and Alloys for Gas Turbines, Iron and Steel Institute, February 1951, p. 181.

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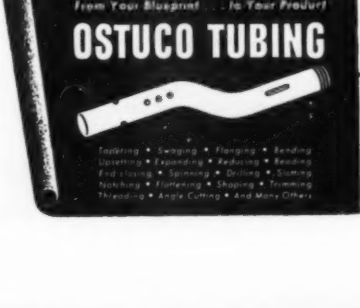

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Fatigue Tests at High Temperatures

(Continued from p. 152)

temperature of the rotating test piece. Elaborate calibration has shown that the present method using a thermocouple placed $\frac{1}{32}$ in. from the test piece is satisfactory.

In the gas turbine, impurities such as sulphur in the fuel will appear in the combustion gases as sulphur dioxide. It was considered possible that serious corrosion might be encountered with nickel-base alloys. Therefore corrosion fatigue tests were undertaken on the more important turbine materials. The tests were run with and without an atmosphere of sulphur dioxide and moisture. The initial work was carried out with a gas concentration of 12% sulphur dioxide but later this was reduced to 0.05% to be equivalent to the maximum concentration in a jet engine burning a 3% sulphur-bearing fuel at an air-to-fuel ratio of 100 : 1.

With a high concentration of gas, the surface showed pronounced attack in the form of a series of circumferential exudations. With low concentration and after 1000 hr. at 1470° F. under alternating stress of 13,400 psi. the surface condition resembled that obtained with a very light etch. The tests at 1470° F. up to 100 million reversals of stress showed only negligible reduction in fatigue strength.

Fatigue tests were run on a steel to find the effect of solid lead compound deposits at 700° C. (1290° F.). The central portion of the specimen was coated with a thin film of corrosion medium whose composition was determined by analyzing deposits occurring on engine valves. A typical analysis was 10.0% C, 18.7% PbO, 70.6% $PbBr_2$ and 0.7% $PbSO_4$. It lowered the allowable stress for 10^7 cycles by about 15%.

Mention is made of a fatigue machine operated electronically to vibrate a rectangular-section specimen at much higher frequency than can be done with conventional equipment. In principle, the mechanism resembles that used in a moving-coil loudspeaker. Using this machine, tentative results on the effect of a cold worked surface on the fatigue strength of Nimonic 80 have been obtained. No appreciable reduction in the hot-fatigue strength of Nimonic 80A was found when the mean stress was zero; cold work reduced the fatigue strength when the metal was subjected to creep stress before testing.

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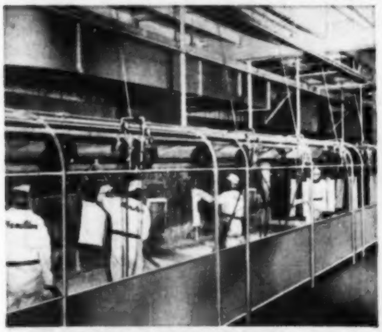

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An accelerated cavitation machine of the vibratory-type was used to investigate a large variety of materials to determine their relative resistance to cavitation, and was used for making investigations of some of the phenomena of cavitation and pitting.

The apparatus consists of a vacuum-tube oscillator which produces an alternating magnetic field through a nickel tube. When the frequency of the magnetic field is the same as the natural longitudinal frequency of vibration of the nickel tube, the tube vibrates at maximum amplitude in this direction.

The test specimen is fastened to the end of the tube and immersed to a depth of ⅛ in. in distilled water which is maintained at 76° F. All tests were made at a frequency of 6500 cycles per sec. and with an amplitude of vibration of 0.0034 in. The criterion for the rate of pitting was the loss of weight of the test specimen, and rolled brass was used as the standard for these tests. The duration of the test was 120 min., as it was found that after this duration a highly polished specimen would pit at the same rate as one having a duller finish.

Tests to determine the effect of amplitude showed that the rate of pitting was constant between amplitudes of 0.0030 and 0.0035 in., and that there was a certain amplitude below which each metal pitted very little.

When the depth of submergence was increased from ⅛ to 2 in., the amount of material removed from rolled brass increased and that removed from cast stainless steel decreased. On both, the area of the surface of the specimens which pitted increased with an increase in submergence. However, the depth of pitting on the brass remained the same for all depths of submergence while the depth of pitting on the stainless steel decreased as depth of submergence was increased. *(Cont. on p. 158)*

*Abstract of "Accelerated Cavitation Research", by W. J. Rheingans, *Transactions* of the American Society of Mechanical Engineers, Vol. 72, July 1950, p. 705.

Cavitation Research

(Continued from p. 156)

Tests were conducted to determine if different liquids had different effects. The general conclusions were that acid solutions did not change the cavitation forces and that weight losses were greatly reduced in oil, alcohol and other liquids. The surface tension of the liquid seems to have an important influence on the rate of pitting; the greater the surface tension, the greater the damage.

The pitting resistance of many standard trade materials were determined to evaluate their suitability to the industry. There was quite a variation in the resistance to pitting of various types of cast stainless steels and even a variation in steels of the same type but made in different foundries. It was also found that differences in hardness affected the resistance to pitting of 12 and 13% chromium steels; the harder material had less loss in weight. This same difference in pitting was found in two stainless steels that were rolled and annealed.

Tests made on welded steels showed that:

1. Two layers of weld give better protection and have greater resistance to pitting than one layer of weld deposit.
2. The use of Type 309 (25% Cr, 12% Ni) stainless steel as a first layer of weld metal tends to reduce the resistance to pitting of the weld deposits.
3. The addition of columbium to the weld rods has no beneficial effects as far as resistance to pitting is concerned.
4. Two layers of Type 301 (17% Cr, 7% Ni) stainless steel weld give the greatest resistance to pitting.
5. If the weld is to be subjected to high stresses, Type 309 stainless steel should be used as a first layer so as to prevent the formation of a martensite boundary which leads to the formation of cracks.

The recommendation based on these conclusions is that two layers of Type 301 (17% Cr, 7% Ni) weld rods be used for prewelding and repairing all hydraulic turbine machinery subject to strong pitting due to cavitation, and where the welds and the base metals will not have high stresses imposed on them. Where high stresses exist, it is recommended that Type 309 be used for a first layer. The use of weld rods containing columbium is not recommended.

The weight losses for three cast

steels were rather high but there was little variation in their performance. Tests of a number of cast aluminum bronzes showed that some of the harder alloys had twice the pitting resistance of the best stainless steel castings. The welded bronzes also showed good resistance to pitting.

Some types of welded "Colmonoy" had a high resistance to pitting, as did some sprayed and fused coatings. However, the coatings on test buttons separated from the basis metal during the vibration tests. Sprayed coatings of stainless steels gave variable results; some pitted rapidly while others performed well, indicating that the method of application is an important factor.

Conclusions — New materials such as the Ampco bronzes, Colmonoy alloys and Thiokol rubber are constantly being developed which might be suitable for hydraulic machinery and might have a distinct advantage over the materials now in use.

The practical application of the materials — such as the number of layers to be used in repairs by welding or when prewelding — influences the resistance to pitting, whereas preheating the base metal has little effect on the resistance.

The hardness of the material has a definite effect on the resistance to pitting, regardless of the material being used.

F. M. REINHART

British Views of Metal Finishing in America*

ONE OF THE few compensating advantages of the present unsettled international situation is the educational program formerly conducted by the E.C.A. (now the Mutual Security Administration) to acquaint foreigners with modern American industrial progress.

This pamphlet is a detailed report of a six-weeks' tour, in the fall of 1950, by a team of 13 specialists from Great Britain that visited 21 plants and 9 technical groups in this country to study methods of polishing, plating, and painting metals. This report includes details of visits to plants and of the cycles in use for typical finishing operations. *(Cont. on p. 160)*

*Abstract of the Productivity Report, "Metal Finishing", Anglo-American Council on Productivity, distributed by Economic Cooperation Association, 2 Park Avenue, Suite 1219, New York 16, N. Y., price 50¢.

Metal Finishing

(Continued from p. 159)

From an American viewpoint, the most significant part of the report is that devoted to conclusions and recommendations which furnish an opportunity "to see ourselves as others see us". Their recommendations to English industry may be summarized as follows:

While more attention should be paid to mechanization, it must be adapted to special needs. Also, cost data should be made available to the whole organization of a plant. It is thought that the American "unorthodox" arrangement of plating shops may provide greater flexibility and economy.

A campaign of education of industry and the public is desirable to emphasize the significance of metal finishing, and much closer collaboration between the design and the finishing departments is necessary. There should be more inspection and quality control in the earlier stages of metal finishing.

The American "kerb-side" standard of finish — for example, on automobiles — should be followed, but not at the expense of durability. It is believed that the prevailing British standards of appearance may be too high in some cases.

New methods of paint applications should be more quickly evaluated and adopted if advantageous, and more study should be given to reclamation of spray paints. The film thickness of paints should be measured instead of merely depending on the number of coats.

More automatic and semi-automatic polishing should be done, with the emphasis on barrel polishing and deburring. Prepolished strip should find wider use.

Semibright nickel plating may be preferable to dull or full-bright plating.

Electropolishing and chemical bright dipping warrant more study, as does periodic reverse plating.

Methods of metal cleaning, rinsing, and activation (of nickel before chromium) are superior in U. S. to those in Britain. De-ionized water may be useful.

The report gives a clear, concise picture of American plating practice in 1950. It shows that the similarities between American and British practice are more pronounced than the differences. Shortages of metals, especially nickel, have since caused radical changes in both countries, most of which, it is to be hoped, will not be permanent.

W. Blum

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This radically new but commercially proven application of the world renowned Ajax Salt Bath Furnace offers industry many unique advantages over any other method for selectively heating the rim or edges of circular objects, hardening teeth on gears or sprockets, and any other products that require peripheral heating.

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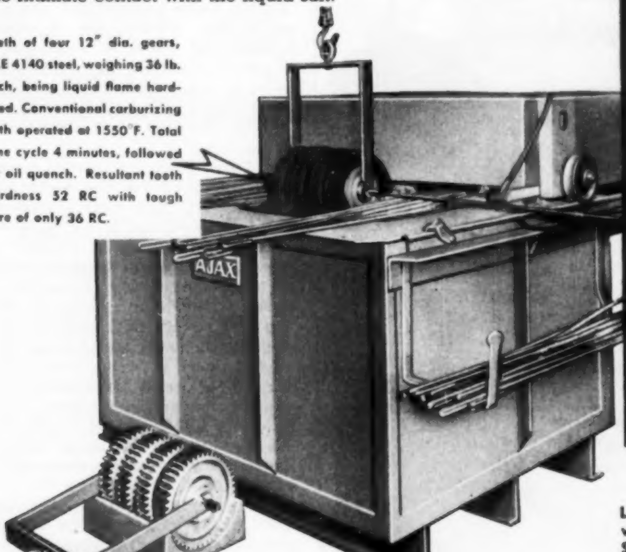

Teeth of four 12" dia. gears, SAE 4140 steel, weighing 36 lb. each, being liquid flame hardened. Conventional carburizing bath operated at 1550°F. Total time cycle 4 minutes, followed by oil quench. Resultant teeth hardness 52 RC with tough core of only 36 RC.

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Explosion Transition of Weldments*

IN TESTING WELDMENTS to destruction, one of the basic objectives is to determine not only the factors influencing the performance of the weldment in the test but also the extent of their influence on that performance. A form of explosion test has been utilized at the Naval Research Laboratory, Washington, D. C., for this purpose.

In this test a 20 x 20-in. plate specimen is placed over a 3-in. thick saddle plate in which a 12-in. diameter chamfered circular opening had been prepared. The explosive, a 4-lb. cast wafer of Pentolite, was supported 15 in. above the test plate and central with reference to the 12-in. hole in the saddle plate. This "offset" or "standoff" of the explosive develops an essentially flat pressure wave of uniform intensity over the test area while area of the test plate supported by the saddle plate (72% of the total) is clamped thereto by the pressure wave during formation of the bulge.

The tests were conducted at temperatures ranging from 25 to −105° F. and test plates were held at the desired temperature for a minimum of 3 hr. prior to testing. An increment loading technique was used which consisted of successive explosions against each specimen until either the desired strain level was reached or fracture occurred. Between shots the specimens were returned to the refrigerating apparatus for a minimum of 1 hr.

Two plate materials were used, one of 52,000 and the other of 38,000 psi. yield strength (henceforth, these will be referred to as HTS and MS). Welds were made of the double-"V" form using electrodes of three grades: AWS E6010, E7016 and E12016. The joint groove in the ¾-in. plate had a 60° included angle with a root opening of ⅛ in. Welds were deposited with a full weave in a total of 8 layers. Joints in the HTS plate were located transverse and parallel to the rolling direction but in the MS plate the joints were transverse only.

Charpy V-notch transition curves were obtained for the weld and plate metals. Base metal specimens were taken parallel to the direction of rolling with notch parallel to the rolled surface of the plate. Weld metal specimens were taken transverse to the joint as close to the top of the weld as possible so that the notch was contained by the surface layer of weld metal. The transition curves of plate metal show a comparatively narrow transition range (from 0 to +50° F.), whereas the weld metal curves show considerably wider transition ranges (from −100 to 75° F.).

In general, the strain distribution in the various welds agreed with previous observations as to the effect of relative flow strengths of weld and base metal, and is summarized in the tabulation.

For the evaluation of fracture performance in the explosion bulge test the final strain at fracture (terminal strain) was considered to be of greatest engineering significance. Three components of this strain may be measured, if necessary:

1 and 2. Biaxial components in bulge surface.

3. Reduction in plate thickness.

(Continued on p. 164)

*Abstract of "Investigation of Factors Which Determine the Performance of Weldments", by C. E. Hartbower and W. S. Pellini, *Welding Journal Supplement*, Vol. 30, October 1951, p. 499-s – 510-s.

Explosion Transition of Weldments

(Continued from p. 162)

The points of greatest interest for such measurements are the site of first separation in fracturing and that location in the pole region, but away from the weld, indicative of the maximum general level of strain accepted by the weldment as a whole.

Flow Strength of Weld Metal	Transweld Strain	Longitudinal Weld Strain
Overmatching the Base Metal	Lessened★	Essentially Unchanged
Undermatching the Base Metal	Increased★	Essentially Unchanged

★Compared to what it would be with matching flow strengths.

At the point of first separation, two strain measurements are practical: *(a)* Longitudinal-weld strain by photogrid (severe strain gradients in the transweld direction prevent the practical measurement of strain); *(b)* reduction of thickness by use of micrometer.

With reference to the latter for an undermatching weld metal, the thickness strain in the weld indicates high terminal strain because of concentration, whereas the over-all general strain level imposed on the weldment at fracture is relatively small. Thus, the measurement of the general thickness strain level for the weldment at fracture, for a realistic evaluation, should be made at a point removed from the weld. A location 1½ in. from the weld centerline, on a radial line through the pole, was selected for this measurement of the general over-all thickness strain level for the weldment. Since all three strain criteria indicate essentially the same transition temperature, the thickness strain measurement at the 1½-in. pole position was adopted as a standard criterion.

On the basis of the thickness strain criterion, the transition temperature ranges were as follows:

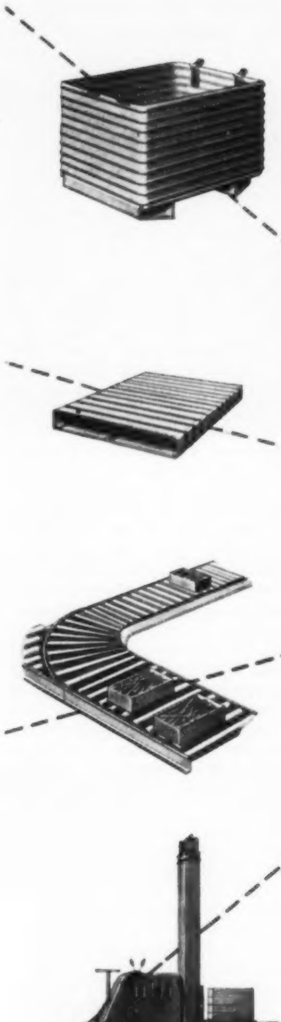
Plate	Weld	Transition Range, °F.
MS	E6010	−50 to −75
	E12016	−95 to −115
MS (not welded)		−95 to −115
HTS	E6010	0 to −75
	E7016	−50 to −75
	E12016	−95 to −115
HTS (not welded)		−95 to −115

No significant differences were observed between the two joint orientations in the HTS plate. Origins of fracture were distributed equally between weld and base metal in the specimens welded with the E12016. Fractures that originated in the weld were found to propagate through base metal rather than in or along the weld. In general, the radiographic quality of the welds did not correlate well with fracture performance. The E12016 weld fractures exhibited surface shear at temperatures above −105° F. but, on the other hand, the HTS plate did not exhibit surface shear at the highest test temperature (−50° F.).

In the HTS plate with E7016 welds the fractures were initiated in the weld and, in most instances, developed through the weld for extensive distances. The site of first separation was not easily determined and surface shear was not exhibited at the highest test temperature (−25° F.).

The HTS plate with E6010 welds withstood greater plastic deformation transweld than did the other weld metals. The fractures were

(Continued on p. 166)



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Explosion Transition of Weldments

(Continued from p. 164)

largely through the weld metal and were characterized by shear at temperatures of −25° F. and above. The HTS plate did not exhibit surface shear at the highest temperature tested (+25° F.).

In the MS plate with the E6010 and E12016 welds the transitions were essentially the same as indicated for the HTS plate, although fracture was initiated in the E6010 weld metal. Also, the E6010 weld in MS plate showed greater ductility than similar welds in HTS plate and, while fractures were transweld, they propagated through the base metal.

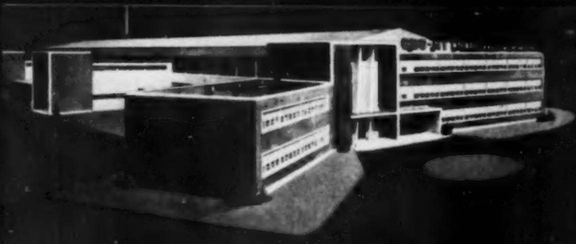
The most evident fact to be noted from these tests is that the performance of the pearlitic steels was controlled by the weld deposits rather than by the heat-affected zone. This suggests the importance of assessing those characteristics of the weld which are primary in the performance of the weldment.

Since the transition from ductile to brittle fracture of the prime plate specimens and the E12016 weldments occurred at the same temperature (although their notch toughness was 15 ft-lb. at 0° F. and 15 ft-lb. at −100° F., respectively) it would appear that notch-bend transition tests cannot be used to indicate performance of unnotched material when cast weld metal and wrought metal are compared. It is possible that the cast weld metal suffers a net disadvantage due to submicroscopic flaws and must have a considerable premium of notch toughness to equal, in the form of a weldment, the performance of rolled plate.

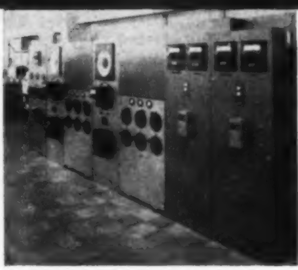
Considering the E7016 and the E6010 weldments, the welds of which had 15-ft-lb. transitions superior to the base metal (i.e., lower temperatures), the transitions of these weldments were inferior to those of the base metal specimens. Thus, it would appear that a moderate premium of weld metal toughness is not enough, and that the premium necessary to produce weldments having transitions equivalent to the prime plate specimens must be very great.

The contribution of absolute flow strength of weld metal to weldment performance is indicated by the increased rigidity of the weldments with welds of high flow strength. The restraining effect of the weld

(Continued on p. 168)



IN THE BEAUTIFUL new plant of CBS-Hytron at Danvers, Massachusetts, de-gassifying of radio and TV tube parts has been set up as an automatic, electronically controlled process. A key factor in making this practical is the dependability of Hayes "Certain Curtain" furnace equipment.



Complete process is 100% automatically controlled

Hayes Inclined-Hood design enables these furnaces to operate on 125 c.f.h. of dissociated-ammonia hydrogen. Operating temperature is 700-800°C.—treating nickel, copper, nickel plated steel, with cooling to room temperature. "Our atmosphere savings are very substantial," notes Mr. Meinerth, "and we are getting more uniform work of ideal cleanliness."

Work goes direct from degreasing to furnaces, passing through special drying units shown here

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ELECTRIC CERTAIN CURTAIN FURNACES

Explosion Transition of Weldments

(Continued from p. 166)

was shown to be proportional to its absolute flow strength. Thus, an increase in load-carrying capacity of the weldment results from the presence of welds of high flow strength. Fractures in overmatching welds initiate and propagate in a transweld direction and those in undermatching welds initiate in and propagate along the weld. This follows as the result of strain unbalance developed by mismatching weld and base metal flow strengths and the fact that fractures develop at 90° to the direction of principal strain. With undermatching, the principal strain is transweld; with overmatching, the principal strain is longitudinal.

It is concluded that the bulge test has considerable research value as well as potentialities as an empirical test tool. Initial use of the test has been aimed at basic research on effect of weld flow strength and it should be pointed out that the present study has been limited to a single geometry of welded joint.

W. L. Warner

New Facilities Increase Openhearth Steel Production*

This paper gives a detailed description of the openhearth furnace operations at the Middletown, Ohio, plants of the Armco Steel Corp. for the past 30 years; high point of the article is the complete description of the engineering and operating features of the new plant built in 1950. Comparisons of the results obtained in the new plant with those observed in the older shops are given. A novel method is employed to charge solid materials in the new furnaces, and this involves a radical departure from conventional openhearth layouts. The new shop includes almost every modern facility for use with openhearths, and the author gives an interesting discussion of the function of each of these items and cites operating data.

The new plant contains three 250-ton furnaces and is compared

(Continued on p. 170)

*Abstract of "A New Departure in Steel Production", by Leo Reinartz, a paper presented at the Chicago Regional Meeting of the American Iron and Steel Institute, Dec. 13, 1951.

New Facilities Increase Openhearth Production

(Continued from p. 168)

with the older plant having eight 175-ton furnaces which the company built several years previously. All of the steel melted in these shops is for sheet and strip containing less than 0.06% carbon. Although the melting charges for these lend themselves to uniform production practices, the steels require a long finishing period and the highest tapping temperatures, both of which reduce the output of the furnace. The new furnaces are severely handicapped at present because of insufficient hot metal (only 26% in 1951 as compared to 41.1% available hot metal on the older 175-ton furnaces). In spite of this the new plant has shown outstanding results as compared to the older one. Some of the comparative results are:

	175-Ton Furnaces	250-Ton Furnaces
Hot Metal	41.4%	26.0%
Tons per Hr. (tap to tap)	13.4	18.9
Million B.t.u. per Ton	4.06	3.24
Total Labor Hr. per Ton	0.73	0.67
Charging Time (Average)	265 min.	272 min.
Roof Life (No. of heats)	146	216
Availability	87.7%	91.1%

It will be evident that when sufficient hot metal is available to the new furnaces, performance will greatly exceed these results. A hot metal supply of 50% of the charge should almost double the tons per hour melted on the old furnaces (13.4 tons), and greatly decrease the heat requirement, labor and charging time for the new furnaces. Since the investment cost and hourly operating charges are much higher on the new furnaces, important benefits will result from the increased hot metal which will be available when a new blast gets into operation.

The unique method for bringing solid charge materials to the furnaces is the most important feature of this plant. Departing radically from conventional practices with its long drags of charging buggies, numerous switching back and forth of charging drags and the many delays incidental to such layouts, the new plant overcomes many of these defects by charging each furnace in a manner which does not interfere with the continuous operation of the other furnaces.

The loading is accomplished by

(Continued on p. 172)

New Facilities Increase Openhearth Production

(Continued from p. 170)

bringing the charging drags into the openhearth building on a curved track. This track leads into the basement under one end of the furnace to be charged; the buggies are uncoupled and lifted by elevator to the charging floor; the buggies are turned 90° on the elevator and then manipulated by the charging machine in front of the furnace doors, the charge dumped into the furnace, and the empty buggies pushed to the elevator at the other end of the furnace where they are delivered to the track in the basement. The empty drags are then hauled to the scrap yard for reloading. Burned lime and repair dolomite are dumped from overhead hoppers into charging boxes without interfering with the flow of steel scrap to the furnaces.

The same careful study of the disposal of the molten steel and slag which are discharged from furnaces is also evident. A 466-ft. long pouring platform provides ample room for empty molds, and a special slag car located in the basement receives "flush slags" through a hole in the charging floor. The flush slags and refuse from the charging floor are removed in this manner without interfering with movement of materials being charged.

E. C. WRIGHT

Solidification of Steel*

THE INFLUENCE of mold materials, metal characteristics, superheat, and mold geometry for the production of sound castings is known only in a qualitative manner. The nature and course of solidification from mold walls of widely differing thermal properties is the elemental object of investigation. Temperature measurements made during solidification were deemed the most accurate method to resolve the problem.

The test castings were 20 in. high and 7¼ x 7¼ in. at the top and tapered to 6¾ x 6¾ in. at the bottom. Thermocouples were embedded in the castings and mold walls in a plane passing through the vertical mid-height of the casting.

(Continued on p. 174)

*Abstract of "Solidification of Steel From Sand and Chill Walls", by H. F. Bishop, F. A. Brandt and W. S. Pellini, Naval Research Laboratory Report 3785, Jan. 4, 1951.

Solidification of Steel

(Continued from p. 172)

All castings were risered and the nominal composition was 0.60% carbon, 0.50% manganese and 0.30% silicon.

The amount of superheat had relatively little effect on the thermal course through the walls. In the early stages of wall heating all wall thicknesses behave as if of the same thickness but, as solidification proceeds, the heat capacities of the various mold walls begin to markedly show their influence.

At the time of interface air-gap formation, the cooling rate is reduced on the casting side. The rapid heating of thin walls causes them to expand and pull away from the casting and this results in a decrease in the rate of heat transfer across the interface.

The heat capacities of the chill walls (2 min. after pouring) are illustrated by outer surface temperatures as follows: 770° F. for 1½-in. walls, 425° F. for 2½-in. walls and 140° F. for walls of 4⅛ in.

Heat from three sources, *(a)* specific heat of liquid metal, *(b)* heat of solidification and *(c)* specific heat of solid metal, is metered from the casting to the mold wall during solidification. Simultaneously with the formation of initial skin the superheat of the remaining liquid is lost very rapidly and the central portion of the casting reaches the liquidus temperature. This temperature level is maintained until the solidification band reaches the casting center where a drop of 125° F. was found to take place within a short time.

Graphical representation is given to show the relation between the thickness of chill wall and freezing time (solidification at the center of the casting is completed earlier with thicker walls). By increasing the wall thickness from 1½ to 2½ in., the final solidification time was reduced about 9%. Superheat necessitates a reduction in flow of solidification heat and delays the start and end of freezing.

The macrostructures of the castings were not markedly changed by changing the wall thickness, but increased superheat produced a significant coarsening of the structure.

A single sand mixture containing 3% moisture was used to prepare all molds having walls of thickness as follows: 2¼, 4⅛ and 7 in. It was recognized that other rammed sand mixtures would have different thermal characteristics.

(Continued on p. 176)

Solidification of Steel

(Continued from p. 174)

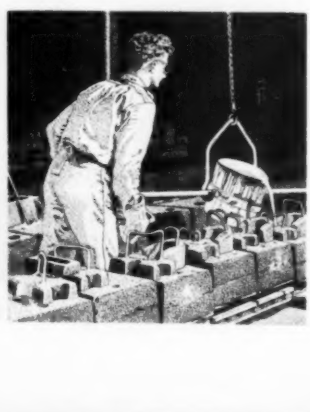
As with chill molds, superheat was lost rapidly and almost all of the cross section becomes isothermal at the liquidus temperature and only a small amount of solid is formed at the surface. The end-of-freeze curves indicate that final solidification does not begin at the surface until solidification has started at the surface. The final freezing wave progresses rapidly through the casting after a small amount of skin has been formed. Increasing the wall caused an increase in final solidification time of 10% when the thickness was changed from 2½ to 4¼ in. Superheat causes a delay in the starting and ending of solidification, the same condition as was found when chill molds were used.

Moisture content in the mold wall hastens solidification during the initial stages by causing the end-of-freeze wave to start earlier. It was found that the end-of-freeze wave of solidification reached the casting center at the same time for green and dry sand molds.

Chill walls transfer an appreciable amount of heat liberated to the atmosphere via the outer mold surface. Sand walls absorb entirely all the heat as specific heat, except for that heat required to vaporize water. Green sand walls therefore do not need to be as thick as dry sand walls.

Steel solidification from chill mold walls proceeds as a band into isothermal liquid at the liquidus temperature, while solidification from sand walls proceeds as start and end waves move from the surface to the center of the casting. Changes in the thermal characteristics of the mold wall alter not only the rate of solidification but also the type of solidification.

D. C. WILLIAMS



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Solders and Soldering*

WARTIME tin conservation measures were frequently found to lead to increased production costs through an increase in the quantity of solder consumed for a given operation, and a greater time required to perform that operation. Today solder economy may be effected by the use of improved techniques.

Quality in 25 to 30% tin-wiping solders is shown by the character of the metal in both the pasty and solid condition. Where a good solder will wipe smoothly and be free from porosity, an inferior material will be excessively friable and frequently cracked in the solid state. It is reported that extensive investigations into the cause of the friable nature of the unsatisfactory solder have so far not yielded a full explanation based either on chemical analysis or microstructure, but that a procedure which ensures the production of suitable material has now been devised. The coarseness of wiping solder can be reduced by the addition of 0.1% arsenic or by stirring sulphur into the molten metal. Porosity can be eliminated by the application of a supplementary layer of low melting alloy, such as the lead-tin-bismuth eutectic, to the joint while it is still hot.

Aluminum parts can be soldered, provided the adherent oxide film is removed. Among the methods suggested for cleaning are abrasion under a pool of molten solder, the use of a suitable flux, or the use of supersonic energy which removes the film by cavitation erosion. Because of inherent electrolytic corrosion hazards, soldered joints on aluminum should be given a protective coating. Among the many solders available for this application, the eutectic of zinc and aluminum is mentioned as having excellent strength and corrosion resistance although its melting point is relatively high. Some of the aluminum alloys are susceptible to embrittlement at the joint when certain of these solders are used.

Repetitive soldering operations can be made economically by using solder preforms, an externally applied flux, and mechanically controlled heating devices. Solder powders mixed with flux have been found advantageous when used as a paint where a multiplicity of joints are to be made.

G. S. PHIPPS

*Abstract of "Solders and Soldering: Some Recent Advances", by H. C. Watkins, *Metallurgia*, Vol. 42, December 1950, p. 372-376.

Graphitization in Low-Carbon Steels*

This paper makes an interesting contribution to the voluminous literature which has appeared since the first important occurrence of this phenomenon was reported in 1943. Over 40 investigations of this matter since then have reported many conflicting opinions on the primary cause of graphitization in low-carbon steels after long exposure in service to temperatures in the region of 500 to 700° C. (930 to 1830° F.). The author states that these prior studies have accumulated sufficient evidence to support the following conclusions:

1. Deoxidation by quantities of aluminum in excess of ½ lb. per ton progressively increases rate at which hypo-eutectoid steels graphitize at subcritical temperatures.

2. Rate of graphitization increases with temperature within the subcritical range.

3. Normalizing from high temperatures reduces the tendency of these steels to graphitize.

4. In welded specimens graphite forms preferentially in the region of the Ac_1 isotherm, forming "eyebrows" corresponding to the individual weld passes.

Two questions of fundamental significance still remained unanswered: *(a)* whether the residual aluminum alloyed with the iron or the aluminum oxide particles are the main cause of accelerating graphitization; and *(b)* whether the graphitization is retarded by increasing the grain size or by some other process during high-temperature normalizing. This paper proposes an answer to these two questions.

The steels used in the study were melted in an 18-lb. capacity induction furnace, deoxidized with 4.5 lb. of aluminum per ton of steel, cast into small ingots, and forged to ½-in. rounds. Each heat was held at 2280° F. for 15 min. after forging. The analyses of the melts were within the following limits:

Carbon	0.20 -0.22%
Silicon	0.23 -0.25
Manganese	0.50 -0.60
Phosphorus	0.015-0.020
Sulphur	0.020-0.022
Residual aluminum	0.14 -0.16

The ½-in. round specimens, weighing about 20 g., were graphitized at 1110° F. for periods of 250 to 2000 hr. After treatment, the samples were cut into three sections; the center slice was for microscopic examination, and the two other pieces (freed from scale and decarburization by grinding) were for chemical analysis. The average number of graphite nodules observed in the different specimens was measured microscopically by counting the number of nodules across the sample diameter at 27 equidistant points at 250×.

Specimens from three steels were graphitized at 1110° F. in air, vacuum and in purified nitrogen. Only a small amount of graphite (less than 10% of the total carbon) was found in samples graphitized in vacuum and nitrogen. No increase in graphite occurred in these samples after 250-hr. exposure up to 1000 hr.

The specimens exposed in an atmosphere of air showed continued increase in graphite nodules from 5% at 250 hr. to 40% after 1000 hr. The author considers that the graphite observed in the vacuum and nitrogen atmosphere specimens is generated by the alumina nuclei

(Continued on p. 182)

*Abstract of "Heterogeneous Nucleation of Graphite in Hypo-Eutectoid Steels", by W. E. Dennis, *Journal*, Iron and Steel Institute, Vol. 70, May 1952, p. 59-63.

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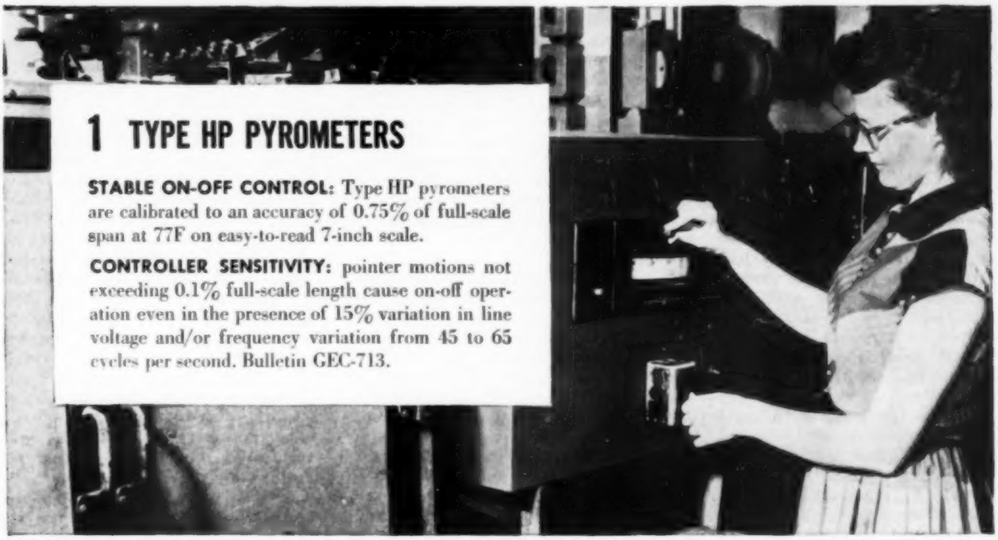

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Graphitization in Low-Carbon Steels

(Continued from p. 180)

contained in the specimens after deoxidation. He further assumes that the continual increase in the amount of graphite with time, which was observed in the samples exposed to air, is due to internal oxidation of residual aluminum to alumina. These provide new nuclei for further graphitization. Although the several steel heats examined showed different amounts of graphitization, all of the data is quite consistent for the samples exposed to air. A confirmation of the internal oxidation of Al to Al_2O_3 was provided by testing smaller samples in air. These showed a faster rate and a larger amount of graphitization, indicating that oxygen diffusion into the specimen is an important factor in graphitization.

The specimens discussed above had all been heated to 2280° F. for 15 min. and air cooled. This treatment generated the optimum grain size in these steels. When other samples were reheated to 2280° F. for a longer time and then exposed at 1110° F., the amount of graphite nodules decreased. Some of these samples were pretreated at 2280° F. in air and some in vacuum but in both instances the amount of graphite always was lower. The author concludes from these results as follows:

1. The original specimens (as-received) have a positive segregation of aluminum at the grain boundaries — a legacy of differential freezing from the melt which is not much reduced by the 15 min. at 2280° F. in the original fabrication used in preparing the samples.
2. Holding for longer times at 2280° F. promotes homogenization through diffusion and retards formation of Al_2O_3 nuclei by internal oxidation.
3. Pretreating at 1650 and 1740° F. also reduced graphitization and reduced segregation of aluminum by readsorption. The optimum amount of graphite was observed at a pretreatment temperature of 1920° F.

The four heats studied, almost identical in composition and deoxidation treatment, exhibited remarkably different susceptibility to graphitization. The author speculates that this may be due to varying degrees of segregation of aluminum in the several melts. Although this may be logical, the great difference between the four heats (80% graphite in 500-hr. exposure for heat A as compared to 34% graphite after 2000 hr. for steel B), it might well be related to the degree of oxidation of the melts at the time of the addition of aluminum.

The author concludes that the accelerated graphitization of hypoeutectoid steel deoxidized with excessive amounts of aluminum is due to Al_2O_3 nuclei and not to residual aluminum content of the steel. Internal oxidation of the alloyed Al to Al_2O_3 during high temperature exposure provides Al_2O_3 nuclei for graphite growth. The effect of pretreatment in the austenitic range is related to the extent that the residual aluminum is segregated at the austenitic grain boundaries, this segregation determining the rate at which the nucleating dispersion can be formed by internal oxidation during graphitization. He further postulates that the chain graphite "eyebrows", observed along the Ac_1 isotherms in welded specimens, result from aluminum segregation in welding, since aluminum is some 30 times more soluble in ferrite than in austenite at that temperature.

E. C. Wright

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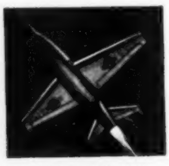

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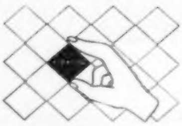

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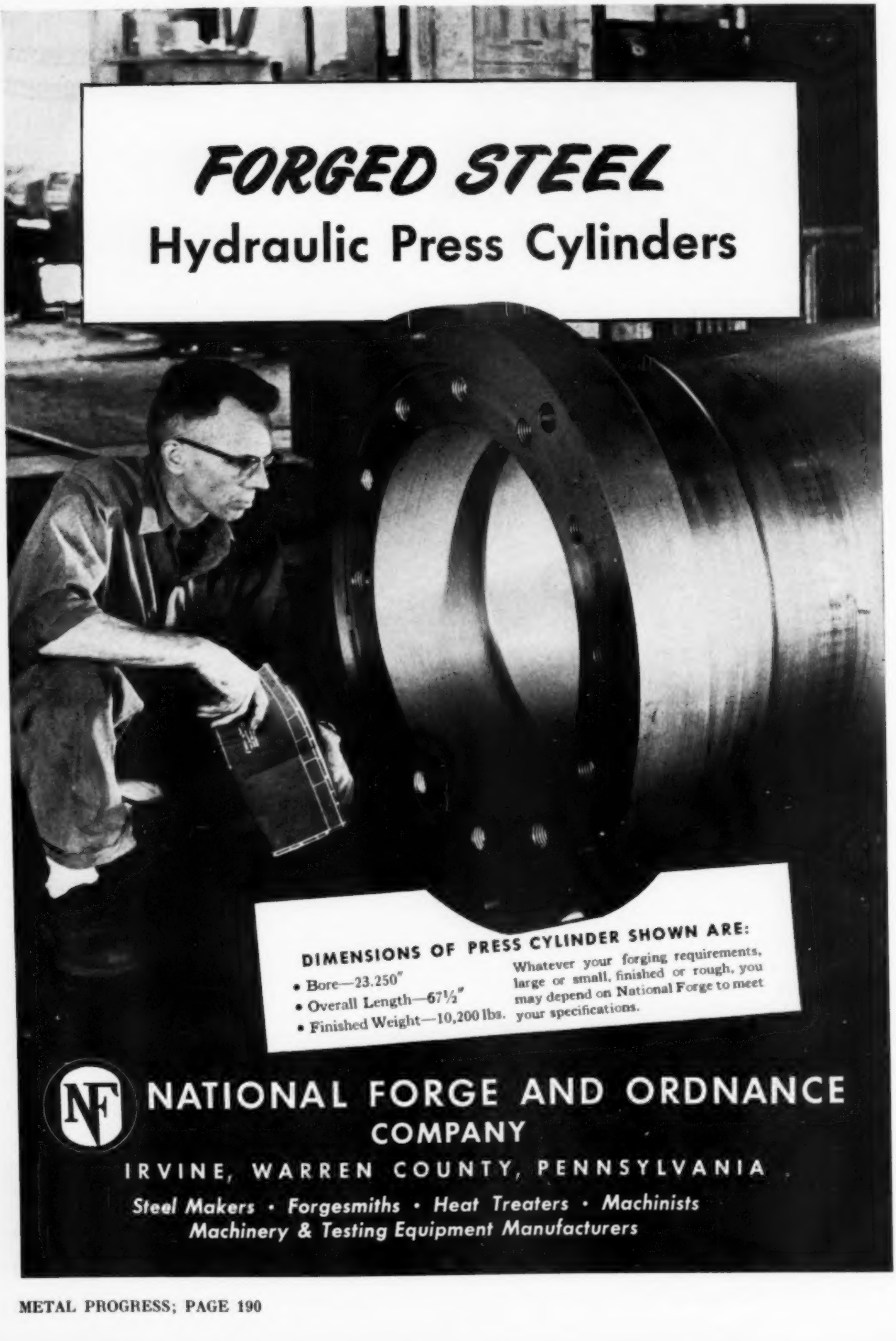
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Selection Factor in Choosing Alloys for Die Castings

		Aluminum Alloys ASTM Nos. S5, SC2	Brass	Magnesium Alloys ASTM Nos. 12 and 13	Zinc Alloys ASTM Nos. 21, 23, 25
Mechanical Properties	Tensile strength	3	1 (Strongest)	3	2
	Impact strength	3	1 (Toughest)	3	2
	Elongation	4	1 (Most ductile)	3	2
	Dimensional stability	2	1 (Most stable)	3	3[a]
	Resistance to cold flow	2	1 (Most resistant)	2	3
	Brinell hardness	3	1 (Hardest)	3	2
Physical Constants	Electrical conductivity	1 (Highest)	2	3	2
	Thermal conductivity	1 (Highest)	2	4	3
	Melting point	2	1 (Highest)	2	3
	Weight, per Cu in.	2	4	1 (Lightest)	3
Casting Characteristics	Ease, speed of casting	2	3	2	1 (Easiest)
	Maximum feasible size	1 (Largest feasible)	2	1 (Largest feasible)	1 (Largest feasible)
	Complexity of shape	1 (Greatest possible)	2	1 (Greatest possible)	1 (Greatest possible)
	Dimensional accuracy	2	3	2	1 (Most accurate)
	Minimum section thickness	2	3	2	1 (Thinnest)
	Surface smoothness	2	3	2	1 (Smoothest)
Cost	Die cost[b]	2	3	2	1 (Lowest)
	Production cost	2	3	2	1 (Lowest)
	Machining cost	2	3	1 (Lowest)	1 (Lowest)
	Finishing cost[c]	3	2	3	1 (Lowest)
	Cost per piece[d]	2	3	2	1 (Lowest)
Extent of Use		2	4	3	1 (Most used)

Source: Materials & Methods

[a] *Through the use of a low temperature annealing treatment, Alloy No. 23 can be made virtually stable in dimensions.*

[b] *Dies for casting the low melting point alloys are least expensive and have longest life.*

[c] *Includes polishing and buffing expense as well as ease of applying all types of commercial finishes, both electrodeposited and organic.*

[d] *Based on die, material and fuel costs, production speed, machining and finishing costs.*

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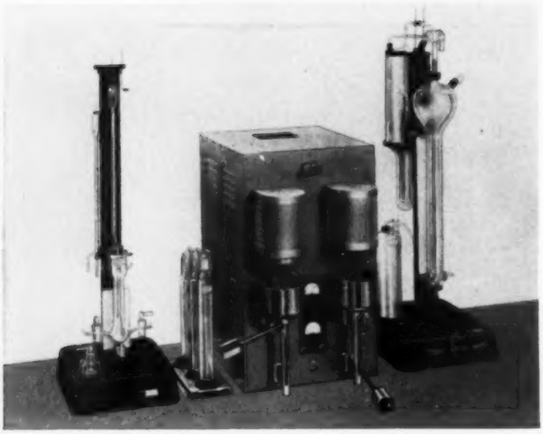

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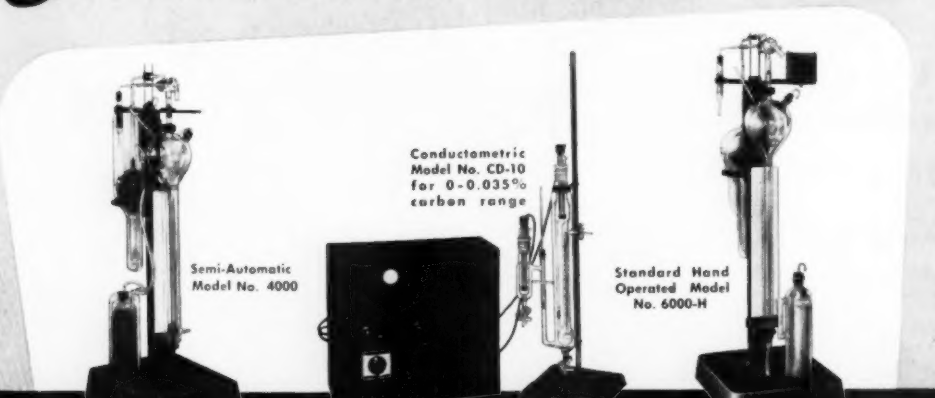

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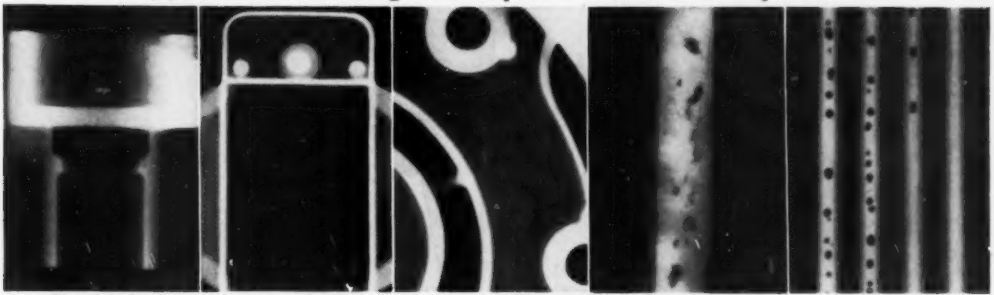

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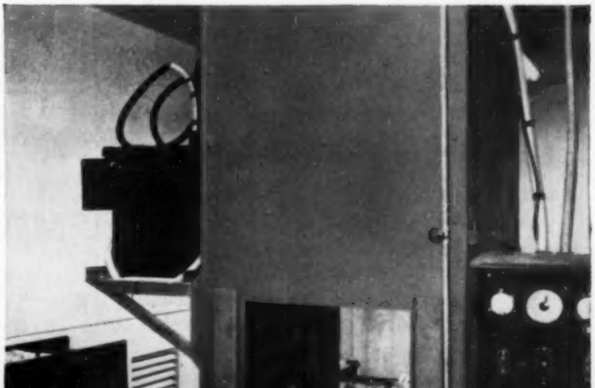
This unit is designed for fast, economical inspection of materials like aluminum, magnesium, plastics, and handles sheets, tubes, rods — as well as cast sections.

Compact, flexible, fully protected and safe, the OX-140 features full built-in radiation protection without the expense of special rooms. "Open down" doors guard against operator injury. The doors also automatically initiate x-ray exposure on closing.

If you have an inspection problem in your plant, call the GE x-ray representative near you. The OX-140 is just one of many x-ray units General Electric has developed to help industry do a better job . . . faster. For literature, write X-Ray Department, General Electric Company, Milwaukee 1, Wisconsin, Rm. AS-9.



Semi-automatic OX-140 has two tables on either side that support pre-setup trays of parts on ball bearings. Work moves continuously because personnel doesn't have to leave the room during exposure. One aircraft company radiographs four times as many parts with their OX-140 as they formerly had been able to inspect with conventional unit. Fewer man-hours are needed.

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- Thirty inch (30") clearance between screws—easy to work with large specimens. Rugged four-column construction—rigidity for off-center loads and high columns.
- Loading and weighing units independent of each other—no shock transfer.
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- Fool-proof SelecΦrange Indicating System—load range selected is automatically color lighted to match colored divisions on 28" dial. Soft-view indirect dial lighting.
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- Change ranges at flip of a switch while under test.
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7301 Euclid Ave., Cleveland 3—UTah 1-0200

PUBLISHED BY AMERICAN SOCIETY FOR METALS, 7301 EUCLID AVE., CLEVELAND 3, OHIO—W. H. EISENMAN, SECRETARY

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Galvanizing Aluminizing Bright Annealing and Normalizing Strip ------ Continuously

Strip in single or multiple strands up to a total width of 54" may be bright annealed or normalized, continuously, in this EF gas fired radiant tube installation. Capacity 7200 lbs. per hour.

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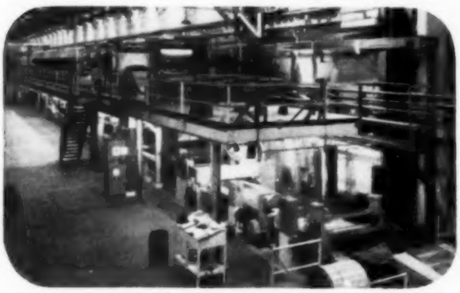
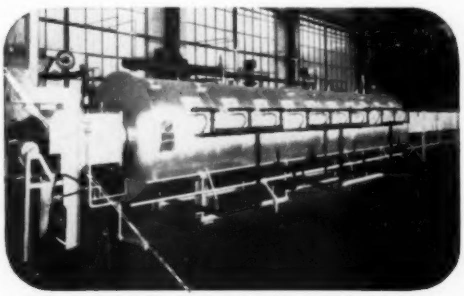
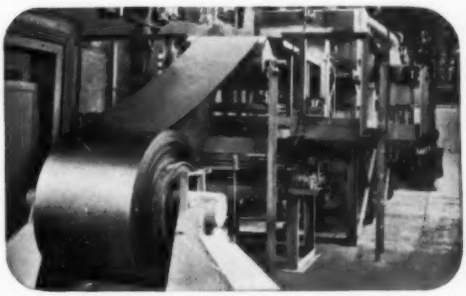


A large capacity continuous strip normalizing, annealing and galvanizing unit. This is a combination EF gas fired radiant tube and electrically heated installation and is over 400 feet long.



Stainless steel strip is bright or process annealed, continuously, in this EF gas fired special atmosphere tube muffle type furnace. It also handles other strip requiring lower temperatures.



An EF special atmosphere furnace with flame preheating burn-off or oxidizing section, and controlled heating and cooling zones for producing various surface conditions on strip.